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MONTHLY WEATHER REVIEW

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INVESTIGATIONS OF ATMOSPHERIC PERIODICITIES AT THE GEOPHYSICAL INSTITUTE, LEIPZIG, GERMANY

By B. HAURWITZ

[Blue Hill Observatory, Milton, Mass., August 1933]

Careful studies of atmospheric periodicities have been made at the Geophysical Institute of Leipzig since 1923 under the supervision of Dr. Weickmann, the director. The following paper gives a short account of the methods used and some of the results found. The study of a wave having a period of 24 days will be dealt with in some detail to illustrate the methods employed.

The starting point was the discovery that in barograms there sometimes appear points (the so-called points of symmetry) with respect to which pressure changes before and after are surprisingly symmetrical.[1] Figure 1 gives seven examples of such points of symmetry that occurred during winter months from 1923–24 to 1929–30, inclusive, in London. The *full* line is the pressure curve constructed from the morning observations. The time scale is indicated on the upper margin for each year. The *dotted* line is the reversion of the original curve from the point of symmetry whose date is indicated by the vertical line in the center of each pair of curves. One such point occurred on January 16, 1924 (fig. 1). The lower horizontal axis gives the time scale for the reflected curve. Thus each date on this axis, which is n days after the date of symmetry, corresponds to a date on the upper horizontal axis, n days before the point of symmetry, and similarly for the pressure values shown by the two curves. Figure 1 shows that the general type of a curve and its reversed image agree very well and that often even indentations of the two coincide.

In some cases it is necessary to contract or expand uniformly the parts of the curve remote from the point of symmetry. This is more often required when a long interval of time is involved. According to Weickmann it is not surprising that such a change in the time scale has to be made because we compare different seasons of the year having especially different temperatures when we compare a very extended pressure curve with its reversed image. It is not to be expected that the waves (which cause the points of symmetry, as we shall see) can have the same velocity of propagation in the different seasons. Therefore, this change in the time scale seems quite justified from the physical point of view.

We shall get a better conception of the conditions for the creation of these points of symmetry, if we remember that a simple sine or cosine curve is symmetrical about its maximum and minimum points. A curve composed of a number of such curves has its points of symmetry where extreme values of all the single components coincide. It is not necessary however that all the component curves have maxima or all minima at this point. Some may have maxima, some minima. It is very easy to visualize this condition by considering a curve composed of only two harmonic components. For details we refer to the published papers.[2]

Since points of symmetry occur in a curve composed of harmonic terms, it is obvious that the points of symmetry in the pressure trace indicate that the pressure curve is composed of harmonic components, the extreme values of which coincide on the date of the point of symmetry (this statement is not exact, but sufficient for our purpose). On the other hand every curve which satisfies certain very general mathematical conditions can be decomposed into a series of harmonic terms. But this is of meteorological interest only when one, or but a very few components, have much higher amplitudes then the other terms, because only then may we suppose that these components represent real waves. Thus we see that the points of symmetry form excellent criteria of epochs of periodicity.

As an example we choose the results of the analysis of the air pressure curve from November 25, 1923, to February 22, 1924. The point of symmetry occurred on January 15. The harmonic analysis of this period of 90 days resulted for the first 20 components as follows:

Length of period (days)	90	45	30	22.5	18	15	13	11.3	10	9
Amplitude	1.68	1.17	1.07	6.73	2.22	2.21	.76	2.34	1.11	1.46
Phase (degrees)	202	353	69	171	150	318	294	286	172	205

Length of period (days)	8.2	7.5	6.9	6.4	6.0	5.6	5.3	5.0	4.7	4.5
Amplitude	2.81	1.00	1.59	.82	1.86	1.21	1.45	1.37	1.22	1.44
Phase (degrees)	23	95	121	212	89	294	75	317	279	191

The periods of 22.5, 18, 15, 11.3, and 8.2 days have amplitudes larger than 2 mm, and thus we may suppose that these periods, or at least some of them are real and not merely byproducts of calculation. The first trace of figure 2 shows the actual pressure curve (A), the second the sum of all 20 components given above (A^*), the third the sum of the five components with amplitudes larger than 2 mm (A_1). This curve agrees quite well with the general features of the original pressure curve. Finally in figure 2 are shown the five single components with amplitudes larger than 2 mm. Note especially how the extreme values of all five components coincide at the date of symmetry.

For those who wish to search for points of symmetry it may be mentioned that the pressure curve in figure 2 was drawn from the morning and evening values. But later investigations showed that it is sufficient to use the morning observations only.

Further, we should note that points of symmetry appear mostly near the solstices. The points of symmetry

[1] L. Weickmann. Wellen im Luftmeer. I. Mitteilung. Sitz.-Ber. Sächs. Akad. d. Wiss. Math.-Phys.Kl. vol. 39, no. 2.

[2] Comp. in Weickmann, loc. cit. chap. 1 by L. Lammert. We have here mentioned only the single not the double points of symmetry, which are less important.

which occur during the wintertime are generally better pronounced than those which occur in summer, owing to

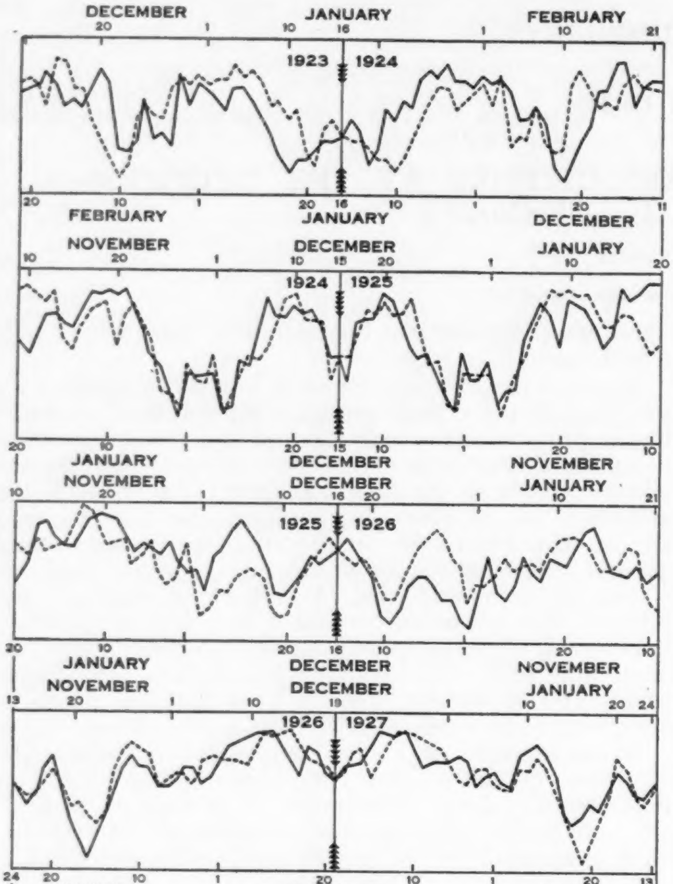

FIGURE 1.—Points of symmetry in the London winter barograms, 1923–30; full lines, actual curves; dotted, reversion curves. (Beitrage zur Geophysik, vol. 34, p. 244, fig. 1b.) 1931.

the fact that the barograms during the wintertime have more characteristic features than those of summer, when the pressure range is less pronounced.

The investigations showed that a period of 20 to 24 days is very common in winter. We shall now illustrate the method of the further investigations on this particular

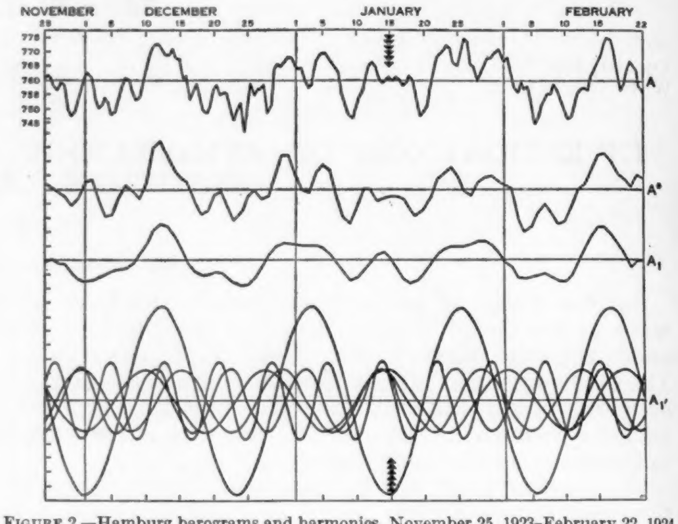

FIGURE 2.—Hamburg barograms and harmonics, November 25, 1923–February 22, 1924. Point of symmetry, January 15, 1924. (Met. Zeitz. vol. 44, p. 248. 1927.)

period which in some winters has great influence upon the European weather.

In order to get a better idea of the physical nature of the periods found it proved very useful to investigate these periods not only at a single place but to represent

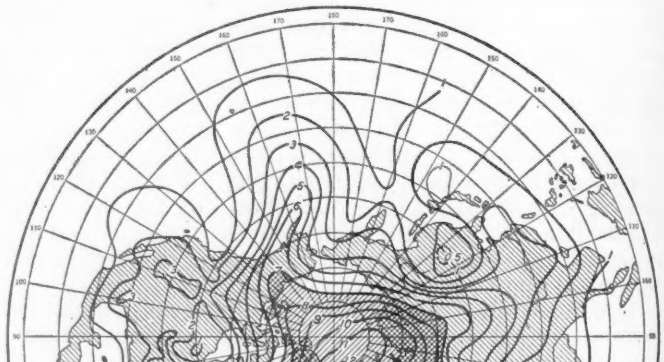

FIGURE 3.—Amplitude of the 24-day pressure wave, winter of 1923–24. (Met. Zeitz. vol. 44, p. 249. 1927.)

the distribution of their amplitudes and phases over a wider area by means of maps. That was first done by Mildner.[3] He dealt with the 24- and the 8-daily wave for the period from December 10, 1923, to February 19, 1924. (Point of symmetry Jan. 15, 1924.) The distribution of the amplitude of the 24-daily wave during

[3] P. Mildner, Ueber Luftdruckwellen. Veroeff. Geophys. Inst. Leipzig. II. Ser. vol. III, 3. Mildner has chosen an interval of 72 days instead of 90 days in order to obtain whole numbers for the shorter periods. Therefore we have now a period of 24 instead 22.5 days with a large maximum.

the winter 1923–24 over the northern hemisphere is shown in figure 3. This figure gives the result of Mildner's investigation for Europe, completed by Weickmann for the whole northern hemisphere.[4] The amplitudes surround the pole with maximum values at Spitsbergen. The observation material from these northern regions is of course rather scanty, but sufficient to draw the lines of equal amplitudes and phases (or more exactly the phases for the initial time $t=0$). The latter are given in figure 4. They are especially important since they inform us about the direction and velocity of the motion. We take for example the isophase of 90°. At the time $t=0$ all points connected by this line have maximum values. After $24/6=4$ days, all points of the isophase 30° will have maximum values because a time of 4 days corresponds to an angle of 60° and therefore the argument of the sine of points situated upon the isophase 30° is $30°+60°=90°$. The map of the isophases shows also that these are lines around the pole. It is characteristic of the lines of equal phase that they are extended farther south in those regions in which occur most of the cold air outbursts of the northern hemisphere. That gives the impression that the 24-daily period represents a pulsation of the cold polar air masses. This would also explain why its period is greatest in the polar regions.

This opinion is also confirmed by other investigations. Thus Weickmann[5] has shown that this 24-daily wave of the pressure during the winter 1923–24 corresponds to a period of the same length in the temperature. The lines of equal amplitude and phase of this temperature wave have the same features as those of the pressure wave.

Further, a comparison of the behavior of the 24-daily wave at mountain and neighboring valley stations showed that its amplitudes decrease rapidly with the elevation, more rapidly[6] than the ratio P_h/P_o (P_o air pressure at the valley station, P_h pressure at the mountain station). On the other hand it follows from statistical and theoretical investigations that the variability of the pressure decreases quickly with the elevation if the sign of the pressure change is opposite to the sign of the temperature change. In other words, the pressure change is to be explained by temperature changes in the intermediate layer. Thus the pronounced decrease of the amplitude of the 24-daily wave is a result of its thermal nature.

In conclusion we shall give a short account of the theory of the 24-daily wave, which was developed by Schwerdtfeger.[7] This 24-daily wave is according to him a sequence of rhythmic outbreaks of polar air masses as we have seen from figures 3 and 4. Following Margules's formula of the inclination angle of stable boundaries, we may consider the conditions under which a cold mass pushes forward and retires with respect to a neighboring warmer air mass. The main factor is here the temperature difference between the two sides of the surface of discontinuity. If we neglect differences of higher order we may write

$$\frac{\Delta T}{T_1} > \frac{2\omega \sin\phi}{g} \frac{|v_1| + |v_2|}{\tan\alpha}$$

as the condition most favorable for a polar outbreak (ΔT temperature difference between both masses, T_1 temperature of the cold mass, $|v_1|$, $|v_2|$ absolute values of the wind velocities in the cold and warm mass respectively, α angle of inclination of the surface of discontinuity, g

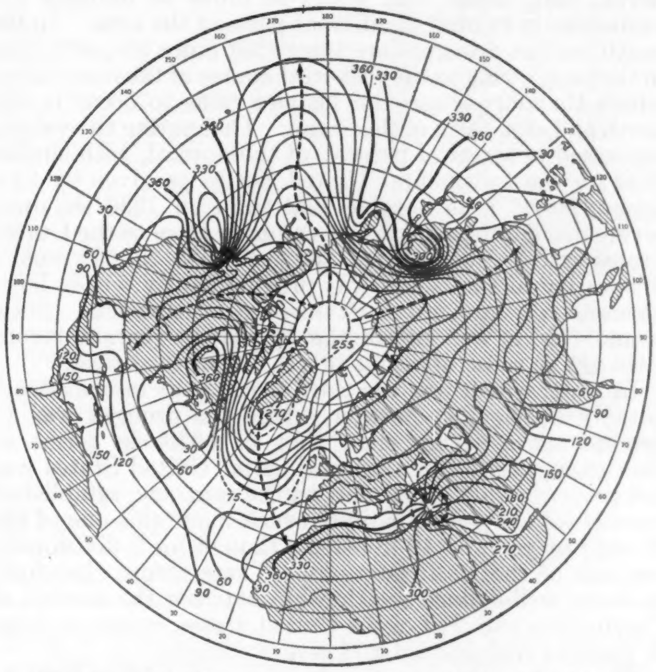

FIGURE 4.—Phase of the 24-day pressure wave, winter of 1923–24. (Met. Zeitz. vol. 44 p. 249. 1927.)

gravity acceleration, ω angular velocity of the earth, ϕ geographic latitude).

Since angles of the inclination 1/100 and 1/200 are to be assumed for the polar surface of discontinuity a temperature difference of between 15° and 25° C. might be the condition of release of a polar outbreak. This temperature difference is brought about mainly by the large scale horizontal heatflow (Austausch). Schwerdtfeger finds by discussion of other possible sources and losses of heat that a temperature difference of about 20° C. between cold and warm air masses up to 5,000 m height will be created during a lapse of 19 to 26 days. If this is so, the pressure and temperature period of about 24 days is explained.

The foregoing is only a very brief account of the investigations mentioned in the title. No reference has been made to work concerning longer periods which certainly will prove very useful for long range forecasting.

[4] L. Weickmann, Das Wellenproblem der Atmosphaere. Met. Zs. 1927, p. 241.
[5] L. Weickmann, Die thermische Wirkung der 24 tägigen polaren Druckwelle des Winters 1923–24. Beitr. Phys. fr. Atm. Hergesellfestband 1929, p. 226.
[6] B. Haurwitz, Luftdruckwellen auf Berg- und Talstationen. Ibid. p. 271.
[7] W. Schwerdtfeger, Zur Theorie polarer Temperatur- und Luftdruckwellen. Veröeff. Geophys. Inst. Leipzig, II. Ser. vol. IV, 5.

WET AND DRY PERIODS IN PUERTO RICO, 1899-1932

By C. L. RAY

[Weather Bureau Office, San Juan, P.R., August 1933]

This paper gives the chronological classification of wet and dry years that occurred in Puerto Rico from 1899 to 1932, inclusive. Following the plan of A. J. Henry's "The Calendar Year as a Time Unit in Drought Statistics" (MONTHLY WEATHER REVIEW, April 1931, vol. 59, pp. 150-154) the island is divided into sections—north, east, south, and west—in order to indicate the variations in rainfall in different parts of the area. In the south portion droughts are somewhat more frequent than in the east, owing to the east-west course of the mountains, which therefore cause the heavier rains to occur in the north and east parts of the island. Comparing the values, expressed in terms of percent of the normal, with similar data for the continental United States as given by Professor Henry, it is notable that while in 1930 the most severe drought on record was common alike to the United States and to Puerto Rico, the year 1933, though second in severity in the island was predominantly wet in large portions of the United States; in 17 divisions (State boundaries) it was one of the 10 wettest years of record although in some divisions it was one of the driest.

In 1907, which was the third driest year in the island, notably in the east portion, where the drought was 11 percent more severe than that of 1930, in terms of deficiency, rainfall in the continental United States was not generally subnormal, but on the contrary, established records for excessive amounts which made this one of the 10 wettest years in 10 divisions, though for 2 divisions it was one of the 10 driest years. There seems, therefore, to be no well-defined relationship between the rainfall of Puerto Rico and that of the United States, except perhaps in years of wide-spread and severe drought.

The comparative figures for the island from 1899 to 1932, shown in percentage of the normal, are given in tables 1, 2, and 3. As will be noted, tables 1 and 2 give the percentages of the normal by years in relative order from 1 to 10. Thus under group 1 is listed the year of least rainfall and percent of the normal for each of the four divisions, and for the island as a whole; under group 2 the year having the second lightest rainfall for each division, etc. A selected list or group of stations was chosen, as follows: North, 24 stations; south, 10 stations; west, 8 stations; east, 4 stations. Data for this selected list are practically unbroken for the given 34 years, and from them division normals were established.

Following the 1930 drought the years 1931 and 1932 were marked by excessive rainfall in the island. In 1931 the heaviest rainfall in 34 years was registered in the east portion and the second greatest in the south, while the island as a whole received the second greatest on record. In 1932 rainfall varied from the fifth heaviest in the east portion to sixth, seventh, and ninth in the west, south, and north, respectively. Comparison of the percentage of the average precipitation in the 3 years of deficient, and the 3 years of greatest, precipitation in Puerto Rico, with a similar grouping for four divisions comprising the continental United States, is shown in table 4 below. The United States group no. 1 includes the Pacific Coast and Plateau States; no. 2 the Plains States and Missouri, Iowa, and Minnesota; no. 3 the Gulf States; and no. 4 the Northeastern States including New Jersey, Pennsylvania, and Michigan. The dependability of the annual rainfall is best indicated by its tendency to adhere closely to the normal from year to year, and it will be noted that Puerto Rico, in terms of this test, compares favorably with the United States groups, as shown in table 4. The no. 4 group of New England States with an extreme range of 49 percent is thus the most dependable of the United States groups, as Professor Henry has stated, owing to this small variation from the normal in extreme years; Puerto Rico closely approaches this figure with a range of 52 percent. Several factors may be said to favor a comparatively small range between the maximum and minimum rainfall years, one of which is the fact that the smaller the average or normal rainfall, the greater is the variation from year to year, or to state it conversely, the greater the rainfall normal, the less tendency for large variation from year to year. Inasmuch as the precipitation normals for Puerto Rico are 42 to 75 inches, representing the south and east divisions, respectively, this factor would be of some weight in explaining the smaller ranges and departures from normal shown from year to year in the island rainfall. Comparing the average deficiency for all droughts in the United States with some of the dry years in the island, the following will illustrate the smaller variations in the Puerto Rico departures.

	Percent
United States, average of all droughts	68
Puerto Rico, drought of:	
1930	79
1923	80
1907	85
1925 and 1929	88
1926	90

The comparatively small rainfall deficiency as related to the normal of course fails to give an adequate indication of the conditions making for drought in the Puerto Rico area. Distribution through the year is an important item, since heavy rains at widely separated intervals may be, in total, a near approximation of the normal, but with periods of weeks or months intervening subject to subnormal precipitation and often severe droughts. Heavy run-offs, and a high rate of evaporation due to long duration of sunshine, are factors which enter quite largely into the production of droughts, in the island, oftentimes when the percentage of departure from the normal is not notably large.

In the tabulation of continental rainfall by years, the tendency is noted for a year of abnormally dry conditions to be preceded by gradually diminishing rainfall and followed by several years of dryness. Such a trend may be similarly observed in the chronological record of Puerto Rico rainfall, to the extent, at least, that there appear to be sequences or unit groups of years with subnormal rainfall. A 5-year sequence of gradually decreasing rainfall led up to the drought of 1923 while that of 1930 was preceded by gradually decreasing precipitation in 1928 and 1929. Wet years appear frequently to come in pairs, as in 1911 and 1912, 1915-16, 1927-28 and 1931-32.

TABLE 1.—*Years of deficient rainfall (percent of normal) in order of relative dryness, Island of Puerto Rico, 1899 to 1932*

Section	Mean	1		2		3		4		5	
		Year	Percent	Year	Percent	Year	Percent	Year	Percent	Year	Percent
North	73.5	1930	76	1923	82	1925	84	1907	85	1918	87
East	75.28	1923	72	1907	74	1926	78	1915	85	1930	85
South	42.0	1929	70	1922	72	1930	72	1910	74	1923	75
West	76.9	1930	87	1923	88	1924	88	1919	89	1915	89
Island	67.4	1930	79	1923	80	1907	85	1929	88	1925	88

Section	Mean	6		7		8		9		10	
		Year	Percent	Year	Percent	Year	Percent	Year	Percent	Year	Percent
North		1929	88	1912	89	1926	89	1913	90	1920	90
East		1925	88	1917	89	1918	92	1914	94	1908	94
South		1907	80	1215	80	1917	81	1921	87	1926	88
West		1910	91	1900	91	1929	92	1905	92	1920	92
Island		1926	90	1918	91	1913	91	1921	92	1920	94

Note: Old Spanish records, San Juan, dating from 1868 show a dry period, approximating the record for 65 years in 1873, annual rainfall 68 percent of the normal and in 1893 67 percent of normal. Canovanas record 1890–98 also has record dry period, 1893 68 percent.

TABLE 2.—*Years of greater than normal rainfall (percent of normal) in order of relative depth, Island of Puerto Rico, 1899 to 1932*

Section	Mean	1		2		3		4		5	
		Year	Percent	Year	Percent	Year	Percent	Year	Percent	Year	Percent
North	73.5	1901	134	1927	132	1931	127	1916	122	1915	117
East	75.2	1931	143	1901	137	1909	125	1916	121	1932	121
South	42.0	1909	148	1931	143	1902	138	1916	134	1900	133
West	76.9	1928	129	1901	127	1927	114	1912	114	1931	111
Island	67.4	1901	131	1931	128	1916	121	1927	120	1902	118

Section	Mean	6		7		8		9		10	
		Year	Percent	Year	Percent	Year	Percent	Year	Percent	Year	Percent
North		1902	115	1899	110	1909	108	1932	108	1928	107
East		1902	120	1905	117	1927	117	1904	115	1924	110
South		1912	124	1932	124	1899	123	1928	122	1901	118
West		1932	110	1904	108	1899	108	1914	106	1902	106
Island		1909	116	1928	114	1932	112	1899	110	1911	107

TABLE 3.—*Percentage rainfall departure from normal by sections: Puerto Rico, 1899–1932*

Year	North	East	South	West	Island
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1899	110	102	123	108	110
1900	101	109	133	91	104
1901	134	137	118	127	131
1902	115	120	138	106	118
1903	94	99	107	103	98
1904	93	115	109	108	101
1905	94	117	108	92	100
1906	96	96	97	98	96
1907	85	74	80	94	85
1908	93	94	96	93	94

TABLE 3.—*Percentage rainfall departure from normal by sections: Puerto Rico, 1899–1932*—Continued

Year	North	East	South	West	Island
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1909	108	125	148	100	116
1910	101	98	74	91	95
1911	106	107	113	103	107
1912	89	96	124	114	103
1913	90	96	94	93	91
1914	93	94	91	106	89
1915	117	85	90	89	102
1916	122	121	134	97	121
1917	104	89	81	97	97
1918	87	92	93	99	91
1919	98	99	100	89	97
1920	90	96	104	92	94
1921	90	99	87	101	92
1922	91	95	72	106	88
1923	82	72	75	88	80
1924	104	110	111	88	105
1925	84	88	80	106	88
1926	89	78	88	99	90
1927	132	117	104	114	120
1928	107	109	122	129	114
1929	88	105	70	92	88
1930	76	85	72	87	79
1931	127	143	143	111	128
1932	108	121	124	110	112

TABLE 4.—*Percentage of the average precipitation in the 3 years of deficient and the 3 years of greatest precipitation in the groups of States, no. 1 to 4, and in Puerto Rico*

Groups	Least			Greatest			Range
	1	2	3	1	2	3	
No. 1	59	65	67	167	149	136	108
No. 2	64	72	77	143	133	129	79
No. 3	74	77	82	136	126	123	62
No. 4	78	83	84	127	120	116	49
Puerto Rico	79	80	85	131	128	121	52

TABLE 5.—*Comparative data on the rainfall in Puerto Rico during 1932, by sections, inches rainfall, and percent of normal*

	North		East		South		West		Island	
	Inches	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*
January	6.36	131	4.62	121	1.02	71	2.60	111	4.26	121
February	.67	18	1.44	42	.48	26	.70	28	.71	24
March	2.71	66	3.40	103	1.63	97	2.29	63	2.44	72
April	4.34	87	6.89	181	2.60	107	5.04	85	4.30	97
May	11.70	175	10.02	149	10.60	283	14.23	180	11.96	188
June	8.26	145	10.65	148	6.98	190	5.02	68	7.58	134
July	5.90	81	11.13	153	2.25	60	8.79	107	6.07	92
August	6.46	94	9.17	128	7.58	164	11.76	129	7.96	117
September	11.57	155	9.58	104	6.69	118	17.11	182	11.28	149
October	7.21	103	9.63	102	4.20	65	9.75	100	7.21	94
November	6.80	84	7.82	88	4.85	104	5.11	69	6.11	85
December	6.38	104	6.46	131	3.14	174	2.23	68	4.83	109
Year	78.36	108	90.81	121	52.02	124	84.63	110	74.71	112

STORM TYPES AND RESULTANT PRECIPITATION IN THE SAN DIEGO AREA

DEAN BLAKE

[Weather Bureau, San Diego, Calif., 1933]

At the request of engineers and water conservationists of southern California, who are not satisfied with the rate and intensity alone of the rainfall but wish also to know something of its origin, tables were prepared which segregated storms in San Diego County into four groups according to their genesis. Weather maps of the north Pacific Ocean are available in San Diego for only the last 5 years, hence the data could not be carried back farther than 1929.

From available weather-reporting stations in San Diego County, 3 were selected, San Diego, 87 feet elevation, Cuyamaca, 4,677; and Warner Springs, 3,165. The criteria were length and dependability of record, elevation, and surrounding topography. San Diego was considered as representative of the coastal, Cuyamaca the mountain, and Warner Springs the intermediate rainfall regimes. Warner Springs in particular is well located for a rainfall study, for it is surrounded in all directions by moderately high mountains, and the effects of the dynamical or ascensional cooling of the rain-bearing winds here are nearly equal, regardless of the direction from which they come. On the other hand, the rain gage at Cuyamaca is exposed in a draw, and records very heavy rains when winds are from the southwest quadrant. In fact, it is located at one of the rainy spots of southern California.

From data of the three stations, three tables have been compiled: (1) The total number of days and amounts of

rain from storms of each type; (2) the number of days, amounts and percentages of precipitation for each of the five seasons produced by storms of each type; (3) seasonal precipitation and departures from the mean. There is little difference in the number of rainy days at the stations, so the figures for San Diego are accepted as representative of all three. Other tables were prepared, among which was one showing the number of days with four arbitrarily fixed amounts. This afforded an index to the rainfall rate.

At the outset it was realized that the place of origin of many of the storms would be in doubt, lack of data preventing us from tracing their source or their movements in the early stages of their careers.

Four broadly generalized types or groups were immediately apparent. The first, designated the north Pacific type, includes all cases of low-pressure areas that approached the mainland from the Pacific Ocean north of San Francisco. The second, designated the south Pacific type, comprises all disturbances that came from the ocean south of San Francisco and north of the Tropic of Cancer. The third, designated the interior type, contains all active depressions that originated or developed over the plateau regions, the Colorado Valley, or the California interior. (An appreciable number of these were secondary disturbances to parent LOWS passing eastward near the Canadian border or through the Canadian Northwest.) The fourth, designated the Mexican type, consists of the tropical disturbances that occasionally moved northward to southern California from the west coast of Mexico, and also, not logically but as a matter of convenience, the few sporadic thunderstorms of the warmer months, known locally as "Sonoras."[1]

NORTH PACIFIC TYPE

This group ties in naturally with the recognized and fundamental types set forth by Thomas R. Reed.[2] As he states, his westerly types, which may be associated with the north Pacific type of this paper, and have the same characteristics, "run well to the south on many occasions" and when their paths are more southerly than usual, southern California is found within the precipitation area. This type is responsible for most of the rainy days, the largest falls, and the greatest number of days of any given intensity.

The general trend of norther storm tracks is southward with the approach of winter, but not until November is southern California within the precipitation area. The amount of precipitation and the number of days with rain increase until the maximum is reached in January, after which, with the return northward of the storm paths, both become less and end completely in May. It is worthy of note that days with rain are about equally frequent from February to May, while the catch falls off materially, denoting a decrease in energy rather than in the number of storms. This type appears to be the most dependable of the four. Large excesses and deficiencies in seasonal totals seem to be due more often to an unusual number of storms of the other types rather than to wide variations in the north Pacific group.

SOUTH PACIFIC TYPE

Apropos of his easterly type, Reed states:

> LOWS of like origin sometimes form over the southern California coast on the tropical side of an overrunning southwest high, or they may lodge there after running south along the eastern flank of a north-south HIGH which, after their passage, presses inland over the Pacific Northwest in a quasi-enveloping movement.

[1] Sonora Storms, D. Blake. Monthly Weather Review, November 1923.
[2] Weather types of the northeast Pacific Ocean as related to the weather of the north Pacific coast. T. R. Reed. Mo. WEA. REVIEW, December 1932, vol. 60, pp. 246-252.

LOWS of this nature are responsible in the main for storms classified under the south Pacific type. At times, though, disturbances that are associated with Reed's southerly type take the form of a trough, and lie near enough to the coast to bring San Diego County under the domination of the secondary depressions that form in the lower end of the trough. This group is also classified under the south Pacific type.

The appearance of storms in this area is haphazard, and wide variations in number and rainfall amounts are found, but apparently conditions are most favorable for their formation during February, as they have proved to be the best rain producers during that month of any of the four types. They develop from November to March, move quickly, travel singly, and produce warm and not infrequently very heavy rains, particularly at stations where the mountain ranges parallel the coast.

INTERIOR TYPE

By far, the most interesting and complicated disturbances are of the interior type. Storms of this nature correspond to those which are the result of Reed's northerly type. While their breeding place appears to be the Great Basin most of the time, nevertheless they develop anywhere over the far western interior. Their growth and subsequent movements are erratic and hard to predict with any great degree of accuracy. Before the last decade the temptation was to ignore them as potential heavy rain producers. The tables show that in San Diego County 32 percent of the total number of rainy days and about 30 percent of the precipitation resulted from storms assignable to this type, and that 24-hour amounts greater than an inch were frequent. Because of the large high pressure area over the ocean off the coast of California at the time these LOWS form, too little weight usually is given to the drop in barometer that precedes their genesis, and before we are aware of it, general, and in many cases, heavy rain has begun over all of southern California. While interior storms are most active from February to May, they may form in any month of the year. During the last 5 years, however, none was tabulated during July or January.

MEXICAN TYPE

The fourth and last, the Mexican type, is responsible for only a small percent of the whole number, but the amounts of their precipitation at Cuyamaca and Warner Springs are much greater than at San Diego, and add materially to the season's totals. Only occasionally do they cross San Diego County. They originate in the tropics south and west of Baja California, and move northward, and only through chance radio reports from ships that happen to be in their path are we able to follow them. Occurring at a time when fruits and grapes are ripening or drying, they always are most unwelcome. Torrential rains often are the result, at which times damage to property is great, railways and highways suffering heavily. An example of particularly destructive rains of this type was the storm in the Tehachipi Mountains of September 28 to October 1, 1932, where the loss of life was 15 and the damage was estimated to be over $1,000,000.[3] Fortunately they are limited to the period from August to November, and years have passed without one of serious proportions reaching this part of the State.

[3] Destructive rains in the Tehachipi Mountains, Kern County, Calif. M. Sprague, in October 1932 Climatological Data, California section.

TABLE 1.—*Total number of days with rain from each type at San Diego, and total amounts from each type at San Diego, Cuyamaca, Warner Springs, during the last five seasons*

Month	North Pacific				South Pacific				Interior				Mexican			
	San Diego		Cuyamaca	Warner Springs	San Diego		Cuyamaca	Warner Springs	San Diego		Cuyamaca	Warner Springs	San Diego		Cuyamaca	Warner Springs
	Days	Amounts	Amounts	Amounts	Days	Amounts	Amounts	Amounts	Days	Amounts	Amounts	Amounts	Days	Amounts	Amounts	Amounts
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.24	0.38
August	0	0	0	0	0	0	0	0	4	.08	0	0	2	.03	3.03	5.17
September	0	0	0	0	0	0	0	0	1	.04	.05	.01	2	.22	5.30	1.94
October	0	0	0	0	0	0	0	0	3	.41	3.52	2.01	2	1.10	5.52	2.95
November	10	1.66	5.26	2.02	3	.37	1.03	.51	6	1.11	6.35	2.60	2	.78	.63	.41
December	17	5.85	22.97	6.78	5	1.68	2.97	1.52	3	.85	7.72	3.21	0	0	0	0
January	39	11.83	30.04	11.40	7	2.46	13.63	6.08	0	0	0	0	0	0	0	0
February	11	2.05	13.45	4.62	11	5.77	13.68	8.40	10	3.26	11.04	6.69	0	0	0	0
March	9	1.40	5.29	1.87	3	.34	2.09	.51	14	3.11	7.65	3.99	0	0	0	0
April	10	.96	7.99	3.32	0	0	0	0	13	4.30	12.07	4.03	0	0	0	0
May	10	.84	5.51	1.35	0	0	0	0	10	1.80	9.43	5.26	0	0	0	0
June	0	0	0	0	0	0	0	0	4	.12	.16	.06	0	0	.08	0
Total	106	24.59	90.51	31.36	29	10.62	33.40	17.02	68	15.08	57.99	27.86	8	2.13	15.80	10.85
Percent	50	47	46	36	14	20	17	20	32	29	29	32	4	4	8	12

TABLE 2.—*Total number of days with rain and percentages at San Diego, and total amounts and percentages from each type by seasons at San Diego, Cuyamaca, and Warner Springs*

Season	San Diego				Cuyamaca		Warner Springs	
	Days	Percent	Amounts	Percent	Amounts	Percent	Amounts	Percent
NORTH PACIFIC								
1928–29	25	60	5.12	73	25.05	70	8.78	71
1929–30	19	43	4.01	37	15.34	37	5.09	25
1930–31	14	39	4.47	41	8.48	32	3.25	27
1931–32	26	53	6.86	52	30.23	57	8.86	36
1932–33	22	55	4.13	39	11.41	28	5.38	32
SOUTH PACIFIC								
1928–29	1	2	0.10	1	0.73	2	0.28	2
1929–30	6	14	1.51	14	8.95	21	4.76	23
1930–31	11	30	4.42	41	7.40	28	4.87	41
1931–32	5	10	2.07	16	8.41	16	4.60	18
1932–33	6	15	2.52	24	7.91	20	2.51	14
INTERIOR								
1928–29	15	36	1.86	26	9.77	28	3.16	28
1929–30	17	39	4.99	47	12.30	30	6.89	33
1930–31	11	31	1.89	18	9.29	35	2.96	25
1931–32	15	31	3.46	26	11.38	21	8.66	34
1932–33	10	25	2.88	27	15.30	38	6.19	36

TABLE 2.—*Total number of days with rain and percentages at San Diego, and total amounts and percentages from each type by seasons at San Diego, Cuyamaca, and Warner Springs*—Continued

MEXICAN

Season	San Diego				Cuyamaca		Warner Springs	
	Days	Percent	Amounts	Percent	Amounts	Percent	Amounts	Percent
1928–29	1	2	0.02	0	0	0	0.08	1
1929–30	2	4	.22	2	5.06	12	3.87	19
1930–31	0	0	0	0	1.61	5	.78	7
1931–32	3	6	.79	6	3.61	6	3.02	12
1932–33	2	5	1.10	10	5.52	14	3.10	18

TABLE 3.—*Precipitation and departures from the mean at San Diego, Cuyamaca, and Warner Springs during the last five seasons*

Season	San Diego		Cuyamaca		Warner Springs	
	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure
1928–29	7.10	−2.65	35.55	−3.25	12.30	−5.48
1929–30	10.73	+.98	41.65	+2.85	20.61	+2.83
1930–31	10.78	+1.03	26.78	−12.02	11.86	−5.92
1931–32	13.18	+3.43	53.58	+14.78	25.14	+7.36
1932–33	10.63	+.88	40.14	+1.34	17.18	−.60

HOURLY FREQUENCY AND INTENSITY OF RAINFALL AT SAN FRANCISCO, CALIF.

By R. C. COUNTS, Jr.

[Weather Bureau, San Francisco, Calif., August 1933]

[Compare: McDonald, W. F., Hourly Frequency and Intensity of Rainfall at New Orleans, La. MO. WEA. REV., January 1929, vol. 57, pp. 1-8]

The hourly rainfall data for San Francisco present several aspects, the most interesting of which is the decidedly greater frequency of rain during the late night and early morning hours than at midday or in the afternoon. This phase of the rainfall has long been a subject for comment, even by comparative newcomers to this area, but heretofore neither the exact facts nor their causes were known, and comment was based largely on conjecture. Data have been compiled for the 20-year period, 1911–30, which, it is believed, is of sufficient length to at least greatly reduce any effects resulting from pronounced abnormalities. The data were tabulated from the daily records of the local Weather Bureau office. These records contain not only the times of beginning and ending of precipitation but also the hourly amounts, which were extracted from the 24-hour record sheets of a self-recording rain gage of the tipping bucket type. Each 0.01 inch is registered on the sheets in the proper hour division, but occasionally this unit amount may be recorded in 1 hour yet be an accumulation of rain extending over several hours; especially is this true of a drizzle or heavy mist. It is reasonable to believe, however, that such cases are as numerous in any hour as another and that the relation of the total hours with a measurable amount, or the total hourly amounts, is unaffected.

In the first compilation the individual hours with 0.01 inch or more, by months, in the 20 years were counted. The sums obtained showed the trend of the hourly frequency for each of the calendar months but the sums for no month were strictly comparable with those of any other because of the variation in length of the months. To obviate this the sums were reduced to a percentage basis, shown in table 1, by dividing the total hours with a measurable quantity of rain by the total number of hours. In the 31-day months the possible hours for each of the 24 were 620, in the months of 30 days there were 600, and in February, 5 of which were in leap years, the divisor was 565. The annual hourly frequency percentages were found by dividing the number of rainy hours of the same name in all months by the possible 7,305 hours to obtain greater accuracy than the means of the monthly hourly percentages would have given.

TABLE 1.—*Hourly frequency of precipitation, 0.01 inch or more (percentage of possible), 1911–30*

	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
July	0.	0.2	0.5	0.2	0.5	0.	0.2	0.2	0.6	0.	0.2	0.2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
August	.3	.3	.3	.2	.2	0.	0.	0.	.3	0.	0.	.2	.2	.2	.2	0.	0.	0.	0.	0.	.2	0.	0.	.2
September	1.0	1.2	1.2	1.5	1.3	1.5	1.2	.5	.8	.7	.7	.8	.7	1.0	1.7	1.2	1.2	.5	1.0	.7	1.0	.8	.7	1.0
October	2.1	1.8	2.4	3.2	4.0	2.9	2.6	2.6	2.4	2.4	1.6	1.9	1.3	1.1	1.1	1.5	2.4	1.8	1.6	2.9	2.6	1.8	1.8	2.3
November	5.7	6.2	6.7	7.2	7.3	5.5	5.8	5.3	5.5	5.0	5.7	5.3	4.7	4.7	4.0	5.5	6.5	5.7	4.7	5.2	5.7	4.7	4.8	4.8
December	8.9	8.7	9.4	8.7	8.9	8.4	8.9	9.0	8.5	8.4	8.2	7.9	9.2	8.9	7.6	7.9	8.5	7.6	9.0	7.6	8.5	8.4	9.7	9.5
January	11.8	12.1	11.0	12.1	13.2	11.9	13.5	12.3	11.5	11.0	9.7	10.6	9.5	10.8	8.2	8.5	8.9	8.7	9.2	9.4	9.5	10.0	10.5	10.2
February	12.7	12.9	13.1	11.9	9.9	9.0	10.3	9.6	9.4	7.6	7.6	7.1	7.8	7.4	8.5	10.8	10.1	8.5	9.7	9.7	9.2	10.3	11.3	11.5
March	7.1	7.1	6.9	7.6	8.2	6.5	6.8	8.9	7.3	6.1	4.7	5.2	6.3	5.6	5.2	5.6	5.6	6.5	6.0	6.0	5.8	5.8	5.6	6.3
April	4.5	4.5	5.5	4.8	4.3	3.8	4.0	4.8	4.5	4.0	3.5	2.7	2.5	2.7	3.0	3.7	3.0	2.2	3.0	3.0	2.8	3.5	3.0	3.2
May	1.8	2.9	2.4	3.1	2.7	2.6	1.9	2.4	2.6	2.1	1.8	1.5	1.0	1.9	1.5	1.5	1.6	1.8	1.6	2.1	1.9	1.9	1.3	1.6
June	.7	1.0	1.7	.8	.7	.3	.5	.7	.3	.7	.5	.5	.7	.3	.7	.5	.7	.5	.5	.5	.5	1.0	1.2	1.0
Year	4.7	4.9	5.0	5.1	5.1	4.4	4.6	4.7	4.5	4.0	3.7	3.6	3.6	3.7	3.4	3.8	4.0	3.6	3.8	3.9	4.0	4.0	4.1	4.3

Ninety percent of the rain at San Francisco occurs from November to April, inclusive, and as the weather of these months is characteristically the same and the percentages of the hourly frequency of each are in the same ratio as the annual figures, it is necessary to discuss the latter only. The annual hourly percentages in table 1 and the curve in figure 1 reveal one diurnal maximum and one minimum. The maximum begins near midnight and ends about 9 a.m., while the minimum extends over the period from the late forenoon to early evening. Another distinguishing feature of the data is the suppression of the afternoon secondary maximum, which is typical of the greater portion of the United States inland from the Pacific coast.

This afternoon increase in hourly frequency, which is only slightly evident in San Francisco, is the result of showers initiated by convection, generally on warm summer afternoons. But the thermal stratification and pressure distribution over and contiguous to California are unfavorable to the development of precipitation in the lowlands of the State during the summer. Too, the climate of the San Francisco Bay area is essentially marine, so that it is overlain by a stratum of marine air varying in depth from a few hundred to three or four thousand feet, over which, during most of the summer, day and night, there is a layer of air of a considerably higher temperature and lower water vapor content. Convectional type showers cannot develop under such conditions, either in the afternoon or at any other time of the day. Infrequently, and usually in the spring and autumn, the marine air in this bowl is superseded by air of continental origin, which descends from the expansive plateau to the eastward and attains a high temperature from the resulting compression, but is of low water vapor content. This afternoon maximum, however, is reflected to a negligible extent in the wet months.

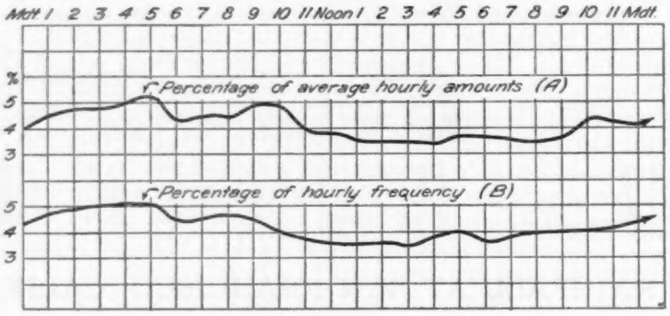

FIGURE 1.

The frequency of rainfall is greatest in any 12-hour period from 9 p.m. to 9 a.m., when 55 percent of the hours with a measurable amount are tabulated, while during the period 9 a.m. to 9 p.m., only 45 percent of the hours are tabulated. In this period extending throughout the night and early morning, the hourly rainfall expectancy is more than 20 percent greater than during the remainder of the day. In the hours when the sun is above the horizon, which averages in the 6 wet months, to the nearest hour, 7 a.m. to 6 p.m., there is an average of 251 hours in the 20 years with 0.01 inch or more, but an average of 283 at night. On this basis the rainy hours are about 13 percent more numerous at night than in the daytime. Of the total number of hours with measurable amounts 38.2 percent are accumulated in an 8-hour interval from midnight to 8 a.m., while only 29.4 percent are spread over an equal period from 10 a.m. to 6 p.m., and the remaining 32.4 percent distributed uniformly in the intervening hours. This discrepancy in the hourly distribution discloses a 30 percent greater hourly frequency of the night period over that of the late forenoon and afternoon and it probably is the wide variation between approximately the hours constituting these two periods that is responsible for the unequivocal impression in the public mind. Rain in measurable amounts occurred in 372 of the possible 7,305 hours between 4 and 5 a.m., a percentage of 5.1, but between 2 and 3 p.m., there were only 251 rainy hours, or 3.4 percent of the possible. This extreme hourly range reveals that rain fell in this night maximum hour 50 percent more often than in the minimum hour of the afternoon.

In the second tabulation the amounts of precipitation in each hour of the day of each month were added together. By dividing these hourly amounts by 20, hourly means were obtained (see table 2). These show that rainfall is also heavier in the night hours than during the daytime. The total amounts (in inches) in each hour of all months were divided by 404.64 inches, the total precipitation at all times in the 20 years, to reduce them to an annual percentage basis, shown by curve (A) in figure 1. This curve is virtually coincident with that representing the percentage of hourly frequency. The diurnal maximum and minimum and the apparent anomaly near 6 a.m. are as definite as in the frequency curve in the same figure. Obviously, the cause operating to bring about this disequilibrium between the frequency of day and night likewise influences the intensity.

TABLE 2.—*Mean hourly rainfall, 1911–30, inclusive*

	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
July	x	x	x	x	x	x	x	x	x	0.01	x	x	0	x	0	0	x	x	0	0	x	x	x	x
Aug	x	x	0.01	x	x	0	0	x	0	x	0	x	x	x	x	0	x	x	x	x	x	x	x	x
Sept	0.01	0.01	.02	0.02	0.02	.02	.01	0.01	.01	.02	.01	0.01	.01	0.01	.01	.02	0.02	.02	.01	x	0.01	0.01	0.01	0.01
Oct	.04	.03	.04	.07	.08	.05	.04	.03	.05	.04	.03	.03	.01	.02	.02	.02	.03	.03	.03	.03	.03	.02	.03	.03
Nov	.09	.11	.10	.11	.09	.09	.08	.10	.13	.19	.12	.09	.08	.07	06	.05	.10	.08	.08	.08	.07	.13	.11	.09
Dec	.16	.16	.16	.18	.12	.14	.14	.16	.18	.12	.15	.17	.17	.17	.20	.14	.17	.19	.21	.13	.16	.18	.18	.16
Jan	.21	.23	.26	.24	.32	.20	.20	.18	.23	.20	.16	.18	.17	.18	.14	.11	.13	.15	.15	.16	.16	.19	.20	.18
Feb	.21	.23	.18	.16	.19	.16	.21	.20	.16	.16	.13	.15	.12	.08	.13	.16	.16	.14	.11	.14	.15	.16	.20	.21
Mar	.12	.08	.08	.09	.12	.13	.15	.10	.11	.13	.10	.08	.09	.10	.06	.09	.08	.07	.08	.10	.11	.11	.09	.10
Apr	.05	.07	.07	.07	.07	.05	.07	.10	.08	.08	.04	.03	.04	.03	.05	.07	.03	.02	.03	.04	.03	.07	.05	.04
May	.02	.04	.04	.04	.04	.02	.02	.03	.03	.04	.03	.03	.02	.02	.02	.03	.02	.01	.02	.02	.02	.01	.01	.01
June	.01	.01	.02	x	x	x	x	x	x	.01	.02	.01	.01	x	x	x	x	x	x	x	.01	.01	.01	x
Mean	.08	.08	.08	.08	.09	.07	.08	.07	.08	.08	.07	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.07	.07	.07

x=less than 0.005 inch.

The cause of the more frequent occurrence, and also of the excessive intensity, of precipitation at night is, unquestionably, nocturnal cooling. Observations and studies by meteorologists in recent years show that radiation is a principal factor in the formation and physics of clouds whereas previously it was conceded to be of only minor importance. In a paper, The Summer Nighttime Clouds in the Santa Clara Valley, California,[1] E. H. Bowie ascribes the formation of these clouds to the cooling resulting from the excess of the emitted over the absorbed radiation. His conclusion is as follows: "* * * the formation of stratus clouds over the Santa Clara Valley during the summer is to be regarded as a radiative phenomenon, occurring when the valley is flooded by air of marine origin, rich in water vapor, and when it in turn is overlain by air of quite low humidity. When this situation exists the excess of the outgoing over the incoming radiation is at its maximum at the upper surface of the bay of marine air, and sometime during the night the cooling thus caused reaches the dewpoint, condensation starts and the cloud forms."

If radiation from a moisture-laden layer of air is such a potent factor in the formation of stratus clouds, it follows that radiation must influence, either directly or indirectly, the formation of clouds during a cyclonic regime. After clouds have formed they tend to become unstable as a result of radiation and absorption. D. Brunt[2] gives some estimates of the exchanges of heat by radiation and absorption which show the effect of these in inducing instability in clouds. His theoretical considerations indicate that "at night the base of a sheet of cloud, in virtue of its possessing the radiative properties of a black body, should absorb more heat than it radiates downward, while the top of the cloud sheet should lose more heat by radiation upward than it gains by absorption of the downward moving radiation. Within the cloud sheet the net flow of heat upward or downward is very slight, on account of its black body properties * * * Hence we need only consider the exchanges of heat between the upper surface of the cloud and the atmosphere above it, and between the lower surface of the cloud and the atmosphere and earth beneath it." He cites the observations of Ångström as substantiating his equations for the net exchanges of heat. The net loss from the upper surface of low cloud is about one third of the black-body radiation, nearly one half for medium cloud, and a slightly greater fraction for high cloud. The net gain at the lower surface is roughly proportional to the height, being very small for low cloud. It follows that the tendency towards instability will be more marked in high than in low cloud and would arise largely at the upper surface only of low cloud.

The cooling of a moisture-laden stratum of air by radiation is a maximum at the upper surface and decreases with descent into it. Indeed the temperature might even rise at the lower surface due to absorption of radiation from another stratum of water vapor or cloud below it, or the ground, although this heating would be small in the lower half of the troposhpere. Under favorable conditions cooling throughout the moisture-laden stratum continues until the lapse rate equals that of the adiabatic for dry air, after which any further cooling establishes a superadiabatic temperature gradient and forces turbulence. Although stratus, and many other clouds, do not yield precipitation, or at most only mists, light dirzzles or snow flurries, because of the absence of vigorous ascending currents, nevertheless a layer of air of considerable thickness and heavily laden with water vapor may yield both cloud and precipitation through vertical convection induced, as explained, by its nocturnal cooling. The forecaster is not infrequently confronted with an obvious unstable condition not connected with a cyclonic system in which precipitation occurs during any hour of the day or night. Is it probable that radiation from air of the necessary water vapor content frequently may create this unstable condition through the establishment of a superadiabatic temperature gradient in one or more of the strata. But whatever the origin of instability it does not seem presumptuous to suggest that continued loss of heat from a deep layer of saturated or nearly saturated air may establish vertical convection sufficiently persistent and vigorous to cause precipitation.

The effect of radiation is not confined to instability rain alone but may hasten and intensify cyclonic and orographic precipitation. In a cyclonic process the current of relatively warm moist air is forced to ascend either by overrunning a surface stratum of denser air or by being itself underrun by a colder, heavier mass. In either case dynamical cooling and hence condensation are resultants of the expansion of the rising air. Along the Pacific coast these effects are amplified by orographic features, but the cooling is not unlike that due to a loss of heat by radiation. As the rising air cools by expansion it loses heat simultaneously by radiation to the atmosphere above. The latter effect causes acceleration of the rate of decrease of temperature and a shortening of the time between the beginning of the process and the attainment of the dew point. Condensation follows, but radiation

[1] Monthly Weather Review, February 1933, vol. 61, pp. 40–41.
[2] Notes on Radiation in the Atmosphere, Quarterly Journal, October 1932. R.M.S., pp. 389–418.

continues now from the cloud and intensifies the process involved in forming drops.

It must be concluded that radiation is a factor in all rain-making processes but the methods by which it induces or influences precipitation are necessarily complicated and imperfectly understood. The slightly greater loss of heat by radiation from water vapor or cloud at night unquestionably accounts in part for the more frequent and heavier nocturnal precipitation. C. S. Durst[3] has ventured the following hypothetical explanation of a possible action of radiation:

Below the critical height,[4] however, any particle which forms will lose heat by radiation and will consequently tend to cool the air in its neighborhood with the effect of increasing the deposition of ice or water. Thus above this critical height condensation will tend to be evaporated; below it, drops will tend to grow, until they either fall through the surrounding atmosphere or reduce its temperature to such an extent that instability arises.

Whatever the ways in which radiation influences cloud formation or precipitation, it remains that data about radiation from water vapor in the free air are essential to a better understanding of the processes involved.

[3] Quarterly Journal, R.M.S., April 1933, vol. 59, pp. 125-129.

[4] The height below which there is a net loss of heat by radiation and above which there is a net gain of heat by absorption of radiation from below; above 6 km in southeast England.

NACREOUS AND NOCTILUCENT CLOUDS

By W. J. HUMPHREYS

[Weather Bureau, Washington, September 1933]

Two interesting and important papers recently have been published by Carl Störmer [1] on clouds in the stratosphere, a region commonly free from clouds of every kind.

There are two types of these clouds:

a. The nacreous (from the name common to several languages for mother-of-pearl), figure 1, which occurs at heights of 20 to 30 kilometers above sea level, and

b. The noctilucent (a name already well established), figure 2, which forms at about 80 kilometers above the earth.

The first of these, the nacreous, resembles in places an alto-cumulus lenticularis, or, more exactly, an alto-stratus lenticularis, though presumably it contains much less cloud material than either of these generally does, and is brightly colored like a glorified iridescent cloud. The second, or noctilucent, type seems usually, if not always, to resemble some sort of cirrus. It is silvery, or bluish-white, in color and has been seen in the middle to high latitudes of both hemispheres, but only when the lower atmosphere was in the shadow of the earth and the cloud in full sunshine.

Both these types of stratospheric clouds had been observed and carefully studied long before Störmer made the detailed measurements of them that form the basis of his valuable papers mentioned above; one, the nacreous, by H. Mohn, as early as 1871, and the other by O. Jesse as far back as 1885. Nevertheless their origin still is in doubt.

I propose here to develop a tentative hypothesis as to the origin of these clouds. It may be incorrect, and much of it is old, but even so a logically possible origin, however wide of the mark, is a better aid to the memory than no origin at all, and secures a more willing acceptance of the facts. This hypothesis is that they are produced by the condensation of water vapor just as are all the clouds of the lower atmosphere.

As is well known the stratosphere commonly is 25° C., or thereabouts, warmer, and its base several kilometers lower in high latitudes than in tropical regions. Owing to this temperature difference there obviously must be an interzonal (equator to poles and poles to the equator) circulaton in the stratosphere. Calculation indicates that near the height of 20 kilometers the pressure should be roughly constant the world over and the winds at that level therefore nearly zero, as observation shows them to be. Below this level of equal pressure and mininum wind velocity the air of the stratosphere must flow from the lower to the higher latitudes and next above it, to what height we do not know, counterwise or toward the tropical regions. Evidently this circulation necessitates a corresponding ascent of the air in the stratosphere over high latitudes, with, of course, a greater or less loss of temperature with increase of height. The lapse rate however will be kept small by radiation from below, provided the circulation is gentle.

Suppose the base of the stratosphere at latitude 60° N., say, is 10 kilometers above sea level; that at this level, and just above it, saturation obtains; that the temperature here is 228° A., and that the lapse rate in the stratosphere is zero up to 18 kilometers and then uniformly positive in the region where convection presumably is active. At what temperature would saturation over water (water assumed because these clouds are iridescent, implying diffraction by spherical droplets) occur in this air (specific humidity, or vapor fraction of air, constant) at the height of 25 kilometers, the level, roughly, of the nacreous clouds?

A little calculation shows this to be of the order of 205° A., a temperature that would be approached at the given height if the air in the stratosphere above the 18-kilometer level had a lapse rate of 2.9° C. per kilometer. If the initial relative humidity were only 50 percent instead of 100 percent as assumed, then saturation would occur at the same height, 25 kilometers, if the lapse rate were 3.6° C. per kilometer.

Hence, under the conditions here specified, most of which are in agreement with observations and none contrary thereto, it seems quite possible that in rather high latitudes a thin cloud might be formed in that portion of the stratosphere in which the upward component of the stratospheric interzonal circulation is most pronounced.

So much for the presumable origin of the nacreous cloud. It remains now to consider the noctilucent cloud. Assume that occasionally, at least, in fairly high latitudes the temperature of the upper air is: from 10 to 18 kilometers, 228° A.; from 18 to 25 kilometers, decreasing uniformly to 210° A., from 25 to 35 kilometers, 210° A.; from 35 to 40 kilometers, increasing uniformly to 315° A.; from 40 to 60 kilometers 315° A., and beyond this last level decreasing, 7° C. per kilometer, to an undetermined height. Also let the water vapor at every level be one part in 4,000 of all the gases present, the amount we have assumed to be present at the base of the stratosphere. Also let the composition of the air be substantially constant from the base of the stratosphere up to 100 kilometers, or more, above sea level, except for the variation in the amount of ozone present, the substance responsible for the high temperature, if it exists, at the levels of 40 to 60 kilometers. These suppositions are in harmony with the skip phenomenon of distant, loud sounds, and ozone and auroral observations. Then, if these assumptions are correct, saturation over ice (ice because these clouds do not show iridescence) could again occur and cloud begin to form at a height of 80 to 83 kilometers, roughly, and temperature of about 160° A.

[1] Höhe und Farbenverteilung der Perlmutterwolken, Geofys. Pub., vol. IX, no. 4, Oslo, 1932.
Height and Velocity of Luminous Night-Clouds Observed in Norway, 1932. Univ. Obsy. Oslo, 1933.

FIGURE 1.—Nacreous clouds. After sunset, January 13, 1932; Oslo, Norway, looking WSW. (C. Störmer, Photo.)

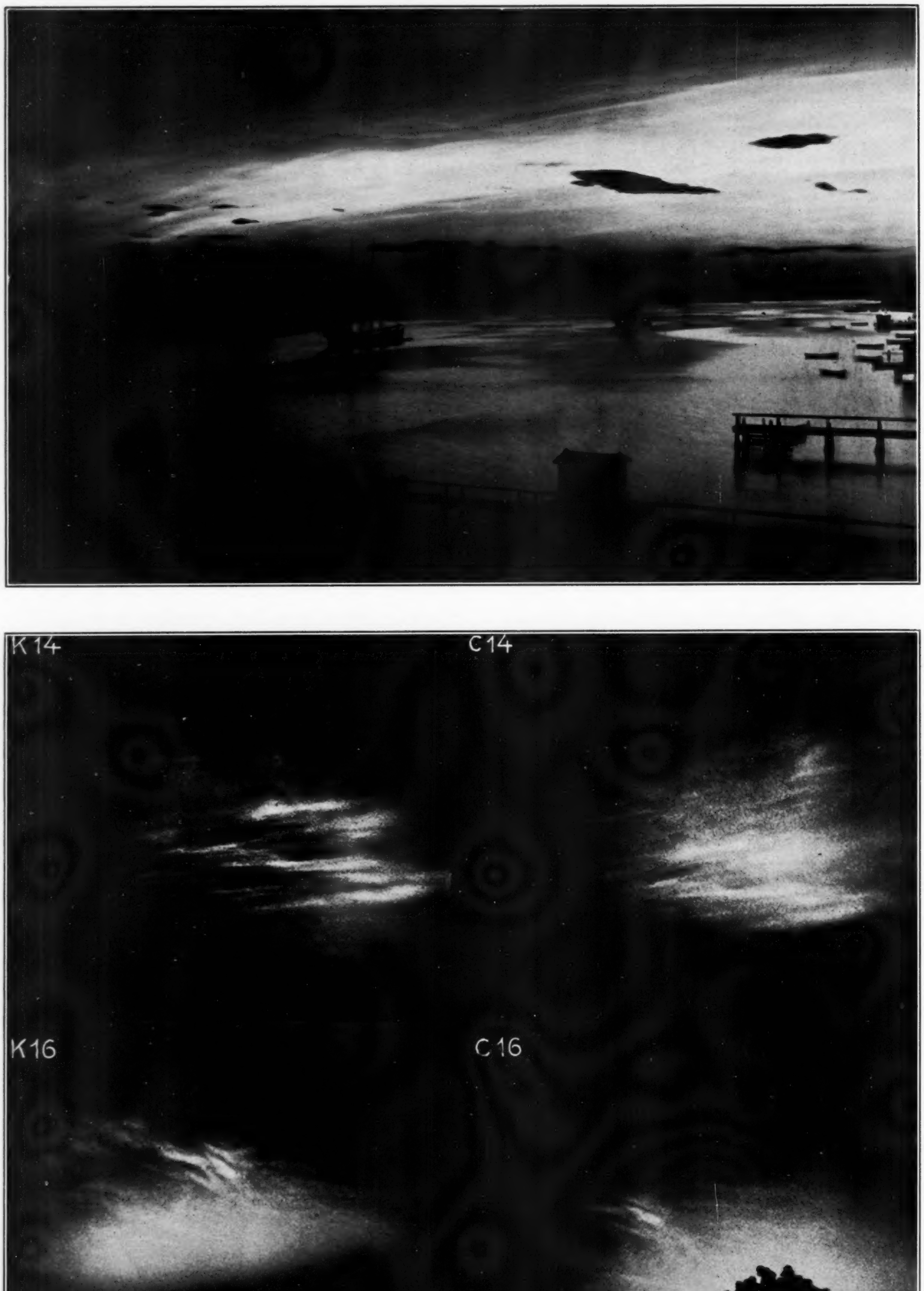

FIGURE 2.—Noctilucent clouds. *Upper*, near midnight, July 27, 1909; Drobak, Norway. (C. Störmer, Photo.) *Lower four*, near midnight, July 10, 1932. (Photographed by direction of C. Störmer.) K-14 and K-16, Konigsberg, Norway. (Busengdal, Photo.) C-14 and C-16, Oslo, Norway. (Tveter, Photo.) The C's and K's were taken simultaneously for determining heights.

If the temperature of the ozone layer is high, as now generally believed and here assumed, then clearly there must be marked vertical convection above it and a correspondingly rapid decrease of temperature with increase of height, or lapse rate, until that particular temperature is reached at which the loss of heat through radiation by a unit mass of the air is equal to its gain of heat by absorption of radiation, at which level a second, or upper, stratosphere will begin.

What the temperature of this second stratosphere is we do not know, but presumably it is lower than that of the first, or under, stratosphere because, mass for mass, its coefficient of absorption is less—less, by experiment, owing to its smaller pressure; and less, by theory at least, owing to its already lower temperature—theory indicating that absorption of radiation by a gas or vapor must decrease with decrease of temperature. At any rate, its temperature may, it seems, be quite low enough to occasionally permit of the formation of super cirrus clouds in its upper portion of sufficient density to be seen when illuminated by the sun while all the lower atmosphere is in the shadow of the earth and therefore free from glare.

As others have suggested, it may be that the water vapor put into the upper air by violent volcanic eruptions has been an important contributing factor to the production of the noctilucent cloud. Such explosions also add condensation nuclei to this high region, though that may be "carrying coals to Newcastle." We may assume that the volcanic water vapor is driven, partly by explosion but chiefly by convection incident to its own high temperature, into the warm ozone layer where none of it would condense, the temperature being too high, and that from there portions of it are carried on up by the convection that persistently must obtain in that region to the level of condensation.

But, we ask, can the water vapor of this source be worth considering—be more than the proverbial "drop in the bucket"? Perhaps so, for the quantity of water vapor given off by volcanoes is very great. It has been estimated, for instance, that during a certain consecutive 18 hours Vesuvius gave out enough water vapor to make a cubic kilometer of liquid water, an amount that would be many drops in the outer air bucket.

It is possible that carbon dioxide may have some part in, or be alone responsible for, the formation of the noctilucent cloud, but not likely, since to solidify it from an atmosphere in which it exists in the usual volume proportion of 3 to 10,000, and at the low pressure that certainly prevails at the height of 80 kilometers, would require a temperature of the order of only 100° A., a much lower temperature than we have any reason to expect at that level, and much lower, apparently, than would be sufficient to produce a cloud of ice particles.

If the above ideas are substantially correct, then the atmosphere consists of the following great divisions, counting from the surface up, namely: Troposphere, stratosphere, ozoneosphere, altotroposphere, and altostratosphere.

MORNING SHOWERS OVER THE GULF, AND AFTERNOON SHOWERS IN THE INTERIOR NEAR CORPUS CHRISTI, TEX.

By J. P. McAuliffe

[Weather Bureau Office, Corpus Christi, Tex.]

A peculiar type of local shower condition occurs near Corpus Christi, Tex., during the summer months, and has such marked characteristics that it has attracted the attention of meteorologists, and sportsmen who visit this coast.

Following an almost cloudless night thundershowers begin forming off-shore over the Gulf about 3 to 4 a.m., and move slowly inland. As they advance toward shore these thundershowers break up into two main storms, one moving northwestward, and the other southwestward, invariably advancing toward the nearest land areas, which are in the directions mentioned. Very few of the storms move directly westward toward Corpus Christi Bay, nearly all appearing to avoid that water area. It is for this reason that the Weather Bureau rain gage records very little precipitation from these showers, as the gage is located on the roof of the Federal Building in down-town Corpus Christi about 1,000 feet west of the Bay. Copious showers occur northeast and southeast of the city during the early morning hours and often the thunderstorms become heavy. Drifting slowly westward these shower conditions reach the interior during the midday and afternoon, and copious and sometimes torrential showers occur north, west, and south of Corpus Christi. During the latter part of the afternoon the clouds dissipate, and by sunset the sky is usually cloudless. This condition is usually repeated 2 or 3 days in succession. The showers are scattered and moderate the first day, more general and heavier the second day, gradually decreasing in intensity and area until the third or fourth day, when no more occur.

When these showers prevail, the early morning air is sultry and the wind generally light, sometimes calm. When the showers reach the shore north and south of the city a moderate breeze that is unusually cool and invigorating comes in from the sea, and the air over the Gulf becomes clear, with visibility unusually good.

An outstanding feature of these thunderstorms is the time of commencement which is almost invariably within the hour following 4 a.m. First thunder usually is heard between 4 and 5 a.m., and the first shower reaches the mainland about 5:30 to 6 a.m. They also traverse almost identical paths as they approach the interior, and for that reason localities along that path have successive days with moderate to excessively heavy rains. In the main the showers are unwelcome, because they come in the cotton-picking season, and delay picking in the areas affected.

It seems that the same general cause, local convection, is responsible for the showers over the Gulf, before sunrise, and over the interior as the day progresses. Since the air is warmer by night over the Gulf than over the land thunderstorms then develop offshore; but as the soil becomes warmer than the water during the day the convection and consequent thunderstorms then occur inland.

Why the showers avoid the crescent-shaped Corpus Christi Bay is not fully understood. The theory is that the land breeze, coming from higher elevations (from sea level to 200 feet within 40 miles westward) converges as a rather strong descending and cool current over the Corpus Christi Bay region, cutting off convectional action in that area, and acting as a barrier to the advancing thunderstorm.[1]

The first showers are practically impossible to forecast, as there is no condition on the weather map to indicate when they will occur. After the rains have started, however, one may assume that the same condition will be repeated the following day, and probably the third day, and forecast accordingly.

[1] The course of the flow of the free air, hence direction of travel of a distrubance in it, is from "source" to "sink"; in this case from water to land. Therefore a storm headed toward the mouth of the bay is likely to be divided into two branches, each moving to, and then over, its nearest land surface.—Editor.

SOLAR RADIATION MEASUREMENTS OBTAINED AT THE BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY DURING THE SECOND INTERNATIONAL POLAR YEAR, AUGUST 1932 TO AUGUST 1933

By HERBERT H. KIMBALL, Research Associate

[Harvard University, Blue Hill Observatory, Milton, Mass., September 1933]

Soon after my retirement from the United States Weather Bureau on June 30, 1932, Dr. Charles F. Brooks, director of the Blue Hill Observatory, asked me to outline a program of solar radiation meaurements for the observatory. Since local conditions seemed favorable, and no systematic series of solar radiation intensity measurements had ever been made in New England, I suggested that the polar-year program as outlined by the International Commission for Solar Radiation be followed as completely as the facilities of the Observatory would permit. This suggestion was adopted, and steps were at once taken to equip the observatory with the following instruments:

(1) A Smithsonian silver-disk pyrheliometer, S.I. no. 63, which was to be used as a substandard instrument.

(2) A 10-junction thermoelectric pyrheliometer, Weather Bureau type, as modified and manufactured by the Eppley Laboratory.

(3) A four-junction thermopile of the Coblentz type, also manufactured by the Eppley Laboratory, mounted in an enclosed box at the lower end of a diaphragmed tube and supported on a telechron-driven equatorial mounting to keep the tube accurately pointed toward the sun. A second and longer tube of heavy cardboard, afterwards replaced by a tube made of galvanized iron, enclosed the smaller diaphragmed tube and shielded it from the wind which sometimes is disturbingly high on the top of Blue Hill, and especially so on top of the observatory tower.

Frequent slight hand adjustments of the tube are necessary to insure accurate pointing.

(4) A set of standard yellow and red glass screens, furnished by the Potsdam, Germany, Magnetic Meteorological Observatory, which were cut from the same pieces of Schott glass as were similar screens furnished to observatories in Europe, and to the United States Weather Bureau. The mean transmission coefficients for these screens have been published in the Met. Zeit., 1932, Heft 6, S. 242–244. Recent tests made at the United States Bureau of Standards, and at the Fixed Nitrogen Laboratory of the United States Department of Agriculture, indicate that the screens furnished the United States Weather Bureau and the Blue Hill Observatory transmit only 0.992 as much as is indicated by the published mean coefficients, due to their cutting off all radiation at a slightly higher wave length (0.004μ) than is given for the mean.

(5) A Leeds & Northrup micromax continuously recording millivoltmeter, with full-scale deflection equaling 5.0 millivolts.

(6) An Engelhard recording microammeter, with full scale deflection equal to 15.0 microamperes, and contacting once a minute.

The color screens are mounted on the tube containing the four-junction thermopile in such a way that the thermopile may receive the unobstructed radiation from the sun, or the radiation transmitted by the red or the yellow screen as is desired. At first these intensities were recorded on the Engelhard recorder, which was of the multiple recording type. The record was not entirely satisfactory, as under the most favorable conditions the individual printing arms did not print dots in a straight line, but in a succession of steps, covering somewhat more than one space on the record sheet, representing a variation of 0.15 microampere. For this reason the thermopile, on May 6, 1933, was connected with the Leeds & Northrup recording millivoltmeter.

At the same time the 10-junction thermoelectric pyrheliometer, which had been recording on the Leeds & Northrup millivoltmeter, was shifted to the Engelhard multiple recorder, which, in the course of a few weeks was exchanged for a single register of the same type, contacting every 30 seconds.

The program of measurements of the intensity of the total solar radiation at normal incidence, I_m, and of the screened intensities, I_y, I_r, has been as follows:

On mornings when the sky is free from clouds in the vicinity of the sun, the cap is removed from the end of the diaphragmed tube above the 4-junction thermopile, the tube is carefully alined on the sun by means of ordinary sights, the telechron drive on the equatorial mounting is set in motion, as is also the recorder in the office room below. At about the same time the Smithsonian pyrheliometer is exposed on a stand on the flat roof of the observatory tower, where the 4-junction thermopile also is exposed.

The Smithsonian instrument is read for a period of 10 or 14 minutes which gives a series of 2 or 3 values of the intensity of the solar radiation at normal incidence. Usually during this same time interval the 4-junction thermopile is exposed to the sun alternately unscreened and with the yellow or the red glass interposed, each exposure being 3 to 4 minutes in length.

In this way, from at least one reading of the series a comparison is obtained between unscreened measurements of the intensity of solar radiation by the Smithsonian pyrheliometer, expressed in heat units (gr. cal/min/cm ^{2}), and by the thermopile, expressed in scale divisions on the record sheet. From comparative readings of this kind obtained at intervals throughout the day, and on all days when sky conditions were favorable, the value of scale divisions on the record sheet have been determined in the above-named heat units. This value has been used to reduce not only the unscreened, but also the screened records of solar radiation to standard heat units. Generally, only slight variations in the reduction factors thus determined have been found from day to day.

On July 19, however, after making the usual adjustments on the 4-junction thermopile, and reading the Smithsonian pyrheliometer, the observer left the recording apparatus in operation—as usual, to go to breakfast. When he returned, he found the air over the observing tower filled with flying ants, some of which had found their way into the diaphragmed tube, and onto the blackened receiving surface of the thermopile. It was therefore necessary to return the thermopile to the Eppley Laboratory for repairs, which resulted in the loss of screened solar-radiation records until August 6.

The radiation intensity measurements obtained as indicated above are given in table 1, columns 4, 5, and 6. They may be used to determine coefficients of atmospheric turbidity, as Ångström[1] has pointed out. In a later publication it is my intention to give such determinations

[1] Ångström, Anders. Atmospheric transmission of sun radiation. Geografiska Annaler, vol. 12, 1930, pp. 130–159.

by a modification of Ångström's method, which has already been outlined in the MONTHLY WEATHER REVIEW, 61:80–83, March 1933.

The total solar radiation received on a horizontal surface from the sun and sky, as measured by the Eppley 10-junction thermoelectric pyrheliometer, which is exposed on the south side of the parapet of the observatory tower, and is in continuous operation, has been summarized in the form of average daily totals for each week, and are given in table 2. The calibration constants accompanying the pyrheliometer, and which depend upon the calibration of a similar pyrheliometer by the U.S. Weather Bureau, have been employed in making the reductions to standard units.

No special difficulty is experienced in determining the hourly averages and the daily totals of solar radiation when the sky is either clear, or covered with a uniform cloud sheet; but when floating clouds of considerable density are numerous the radiation intensity often oscillates rapidly between slightly above zero to slightly above the intensity with a clear sky. In general, therefore, it is customary to determine the average intensity in scale divisions during each 20-minute interval, add together the averages for three of these intervals, and multiply the sum by 20 times the value of a scale division in standard heat units (gr. cal/min/cm^2), as derived from the calibration constants furnished with the instrument after adaptation, if necessary, to the register employed.

The observatory was fortunate in obtaining the services of Miss Harriet Steele, an expert mathematician and statistician, in making these rather tedious reductions.

Most of the Smithsonian pyrheliometric readings, and the records of total and screened solar radiation intensities obtained by means of the 4-junction thermopile, are due to Dr. C. F. Brooks, Director of the Observatory, Mr. E. Monroe Harwood, and Mr. Harry Wexler. The reduction of these records from automatic instruments to heat units, the determination of the apparent time of observations and records of solar radiation intensity from apparent noon, and the corresponding solar altitude and air mass, have mostly been determined by the writer.

TABLE 1.—*Total (I_m) and screened (I_y, I_r) solar radiation intensity (normal incidence) at Blue Hill Meteorological Observatory, Milton, Mass. Lat. 42°12′44″ N., long. 71°6′53″ W., altitude, 635 feet*

[The following abbreviations are used in this table: cld. for cloudy, lt. hz. and d. hz. for light and dense haze, smk. for smoke, v. for visibility (international scale 0–9 with 10 added for visibility greater than 150 km), international (1932) cloud names abbreviations, Beaufort numbers for wind velocity—after wind directions]

Date and hour angle from apparent noon	Solar altitude		Air mass	I_m	I_y	I_r	Sky condition (clouds, haze, visibility, etc.) wind
				gr. cal./min./cm.^{2}			
1933	°	′					
Jan. 15:							
2:28 p.m.	18	03	3.20	1.041	0.778	0.642	Few cld.; lt. hz.; S-3.
Jan. 24:							
3:16 a.m.	18	22	3.14	1.143	.861	.747	Few cld.; hz.; v. 6–7; WSW-5.
0:14 a.m.	28	30	2.09	1.404	.995	.841	Few cld.; hz.; v. 7–8; W-6.
Feb. 6:							
2:27 a.m.	24	01	2.45	1.459	1.045	.868	7 Ci, Cicu; v. 7–8; NW-5.
Feb. 13:							
2:52 a.m.	21	51	2.68	1.178	.855	.732	Few Ci; hz. and smk.; v. 7–8; SSW-5.
0:58 a.m.	32	52	1.84	1.290	.944	.778	Few Ci, Cist, Cicu; hz. and smk.; SW-7.
Feb. 16:							
1:15 a.m.	32	48	1.84	1.404	-------	.830	Few St, few Cu; W-5.
3:24 p.m.	18	48	3.08	1.102	.815	.687	Few Cu; smk.; v. 8–9.
Feb. 21:							
2:15 a.m.	28	54	2.06	1.254	.911	.756	Few Acu; heavy hz.
Feb. 22:							
1:57 a.m.	31	09	1.93	1.333	.973	.796	Few Ci, Cist; hz.; v. 8–9; WNW-4.
Feb. 23:							
1:09 p.m.	37	56	1.62	1.184	.866	.696	1 Cu, fr. cu; hz.; v. 7–8; SW-6.
Feb. 24:							
2:49 a.m.	32	28	1.86	1.184	.874	.706	Few Cist, Cicu, Acu; v. 7–8; W-5.
3:09 p.m.	22	53	2.56	1.130	.852	.706	5 Cu, St cu, fr. Cu; v. 8–9; W-5.
Feb. 27:							
0:07 p.m.	39	26	1.57	1.383	.991	.780	4 Acu; snow flying.
2:07 p.m.	31	44	1.90	1.294	.943	.750	Few Acu; snow flying.
Mar. 5:							
0:54 a.m.	40	13	1.55	1.469	1.021	.826	1 Cu, fr. cu disappearing; v. 9.

TABLE 1.—*Total (I_m) and screened (I_y, I_r) solar radiation intensity (normal incidence) at Blue Hill Meteorological Observatory, Milton, Mass. Lat. 42°12′44″ N., long. 71°6′53″ W., altitude, 635 feet*—Continued

Date and hour angle from apparent noon	Solar altitude		Air mass	I_m	I_y	I_r	Sky condition (clouds, haze, visibility, etc.) wind
				gr. cal./min./cm.^{2}			
1933—Contd.							
Mar. 6.							
3:37 a.m.	21	22	2.72	1.254	0.931	0.768	Few Ci, Cist, Cicu; NNW-5.
2:03 a.m.	34	32	1.76	1.401	1.003	.816	Same as at 3:37 a.m.; v. 9.
0:27 a.m.	41	45	1.50	1.441	1.011	.818	Same as at 2:03 a.m.
0:07 p.m.	42	06	1.49	1.443	1.025	.824	Same as at 2:03 a.m.
1:12 p.m.	39	24	1.57	1.403	.995	.816	2 Ci in S. and W.
Mar. 9:							
2:53 p.m.	29	01	2.06	1.104	.826	.677	2 Cu; v. 8; W-8.
3:38 p.m.	22	02	2.65	.915	.687	.561	Few Ci; v. 8; hz. thickening.
Mar. 10:							
3:07 a.m.	27	13	2.18	1.224	.905	.738	1 Ci, Cicu; v. 9; W-7.
Mar. 11:							
3:15 a.m.	25	35	2.31	1.363	.965	.804	Few cld.; hz. to 10°; v. 10; W-6.
2:04 a.m.	36	10	1.69	1.463	1.017	.848	V. 10.
1:27 a.m.	40	03	1.55	1.483	1.049	.840	Few cld.; v. 10.
0:27 p.m.	42	41	1.45	1.483	1.039	.830	Few Ci, Cicu; v. 10; W-6.
2:55 p.m.	28	35	2.08	1.335	.929	.756	Few Ci, Cicu; smk. and hz.; W-6.
Mar. 16:							
3:27 a.m.	25	58	2.28	1.313	.951	.780	Few Cu, fr. cu; NW-5.
2:55 a.m.	30	48	1.95	1.393	1.019	.832	Few Ci, Cu; v. 10.
2:00 a.m.	38	22	1.61	1.458	1.061	.858	Same as at 2:55 a.m.
1:08 a.m.	43	27	1.45	1.461	1.051	.876	Same as at 2:55 a.m.
0:16 p.m.	45	54	1.39	1.512	1.091	.882	Few Ci, Cist, Cu, fr. cu; v. 10; W-5.
1:10 p.m.	43	18	1.45	1.496	1.085	.876	Few ^{3} Cu; v. 10; W-5.
2:48 p.m.	31	59	1.88	1.377	1.031	.830	Same as at 1:10 p.m.
4:12 p.m.	18	24	3.14	1.136	.886	.722	Lt. hz.
Mar. 17:							
0:16 a.m.	46	18	1.38	1.370	.950	.772	Few Acu; hz.; v. 7; SW-6.
0:28 p.m.	46	00	1.39	1.349	.974	.775	
Mar. 24:							
2:19 a.m.	38	44	1.60	1.271	.862	.731	Few cld.; some hz. and smk.; v 10; NW-3.
0:40 a.m.	48	05	1.34	1.424	1.014	.819	Few Cicu, 1 Cu; NW-4.
0:09 p.m.	49	12	1.32	1.457	1.035	.825	
0:16 p.m.	49	04	1.32	1.443	1.034	.829	
2:08 p.m.	40	09	1.55	1.363	.985	.806	2 Cicu; NE-2.
3:38 p.m.	26	32	2.24	1.174	.905	.734	Few Ci, Cicu, Acu, 1 Cu, St cu; NE-2.
Mar. 25:							
0:38 a.m.	48	44	1.33	1.443	1.033	.826	Few Cicu; NE-2–3.
0:14 a.m.	49	30	1.31	1.435	1.015	.820	Same as at 0:38 a.m.
Mar. 27:							
3:05 p.m.	32	49	1.84	1.236	.876	.722	Ci, Cu, (sun clear); NE-3.
4:01 p.m.	23	25	2.51	1.075	.812	.671	Ci, Cu, (sun clear).
Mar. 29:							
0:53 a.m.	49	25	1.31	1.273	.901	.755	1 Cu, fr cu; v. 8; NW-6.
Mar. 30:							
1:32 a.m.	46	25	1.38	1.430	1.010	.819	V. 10; WNW-6.
0:19 p.m.	51	20	1.28	1.448	-------	.818	Few Acu; v. 10; NW-7.
2:05 p.m.	42	23	1.48	1.368	-------	.810	Few Ci; v. 10; NW-7.
3:09 p.m.	33	01	1.83	1.330	.960	.770	Few Ci, Cist; v. 10; NW-7.
Apr. 5:							
2:58 a.m.	36	38	1.67	1.260	.923	.751	Few Cu, fr cu; lt. hz.; v. 8; W-5.
2:06 a.m.	44	21	1.43	1.374	.962	.786	St cu; sky clear and blue; W-5.
0:53 a.m.	51	56	1.27	1.454	1.012	.822	Same as at 2:06 a.m.
0:26 p.m.	53	20	1.25	1.454	1.012	.820	Same as at 2:06 a.m.
3:19 p.m.	32	55	1.87	1.297	.939	.758	Clear; hz.; WNW-7.
4:48 p.m.	17	23	3.31	1.063	.818	.667	Few Ci in W; W-6.
Apr. 9:							
0:45 a.m.	54	00	1.24	1.408	1.000	.788	2 Ci, few Cu; W-6.
Apr. 10:							
2:17 a.m.	44	22	1.43	1.360	.982	.750	Few Ci, Cu; NE-3.
1:19 a.m.	51	35	1.27	1.384	.990	.778	Cu on horiz; ENE-3.
0:49 p.m.	54	05	1.24	1.404	.988	.778	Few Ci, and Cu; NE-2.
Apr. 11:							
3:00 p.m.	38	00	1.62	1.322	.970	.768	Few Cu; ENE-5.
Apr. 20:							
0:39 a.m.	58	09	1.18	1.398	.966	.792	Few Ci, Cu; lt. hz.; NE-5.
0:16 p.m.	59	07	1.17	1.390	.970	.790	Same as at 0:39 a.m.; v. 7–8.
Apr. 21:							
3:41 a.m.	33	32	1.81	1.258	.901	.741	Few Ci in W; sharp smk. line; W-2.
2:56 a.m.	41	16	1.73	1.309	.914	.741	
1:24 a.m.	54	34	1.23	1.360	.922	.760	2 Ci, in W; Ci- hz. over sun; SW-2.
0:22 p.m.	58	46	1.17	1.386	.964	.780	Thin Cist W to S; hz. to 8°; v. 0–1
Apr. 22:							
3:09 a.m.	39	19	1.58	1.384	.964	.788	2 Ci, Cist, Acu, Ast; N-5.
Apr. 24:							
3:56 a.m.	31	26	1.92	1.267	.882	.738	Few Cist in E.; hz. to 10°; W-6.
1:05 a.m.	51	27	1.19	1.302	.931	.748	Cist in E.; hz. to 10°; W-7.
0:23 p.m.	60	14	1.15	1.322	.931	.756	Few Cist, Acu; hz. to 10°; W-7.
4:20 p.m.	27	03	2.20	.943	.740	.615	Few Cu, Acu; hz. to 13°; W-6.
Apr. 28:							
2:45 a.m.	44	46	1.42	1.387	.995	.788	2 Cist, Cicu; hz. to 8°; SW-3.
0:58 a.m.	59	17	1.17	1.407	1.011	.802	
0:19 p.m.	61	39	1.13	1.358	.967	.780	Few Cist in W.; hz. to 7°; S-3.
May 4:							
2:30 a.m.	48	35	1.33	1.428	.995	.792	Few Cu; lt. hz.; v. 9; NW-6–7.
1:19 a.m.	58	46	1.17	1.445	1.002	.796	Few Cu; lt. hz.; NW-7.
0:48 p.m.	61	49	1.13	1.466	1.004	.798	Same as at 1:19 a.m.
2:26 p.m.	49	14	1.32	1.390	.962	.773	Few Cu; lt. hz.; v. 9; NW-6–7.
5:03 p.m.	21	08	2.76	1.107	.836	.685	Hz.; v. 9; NW-6–7.
May 7:							
0:20 p.m.	64	10	1.11	1.540	1.068	.843	Few Cu; hz. to 5°; NW-6.
May 9:							
0:41 a.m.	63	36	1.11	1.410	.996	.788	2 Ci, Cist, Acu, fr. cu; V. 7–8; SW-3.
0:06 a.m.	65	07	1.10	1.440	1.004	.779	
May 12:							
1:07 a.m.	63	03	1.12	1.202	.873	.682	10 Ci, Cist; ENE-8.
3:59 p.m.	35	04	1.74	.847	.658	.581	1 Ci, few Cu; hz.; ENE-4.

TABLE 1.—*Total (I_m) and screened (I_y, I_r) solar radiation intensity (normal incidence) at Blue Hill Meteorological Observatory, Milton, Mass. Lat. 42°12′44″ N., long. 71°6′53″ W., altitude, 635 feet*—Continued

Date and hour angle from apparent noon	Solar altitude	Air mass	I_m	I_y	I_r	Sky condition (clouds, haze, visibility, etc.) wind
			gr. cal./min./cm.²			
1933—Contd.						
May 15:						
1:19 a.m.	61 40	1.13	1.353	0.954	0.748	Few Cicu, Cist, Cu, Frcu, lt. hz., v. 9; WNW-7.
May 16:						
3:12 p.m.	43 29	1.45	1.314	.926	.724	1 Cicu, Cist, lt. hz.; S-2-3.
May 17:						
0:19 a.m.	66 46	1.09	1.400	.968	.769	Few clds.; hz. to 6°; N-3-4.
0:16 p.m.	66 52	1.09	1.389	.964	.765	Same as at 0:19 a.m.
3:05 p.m.	45 00	1.41	1.261	.932	.716	Few clds.; hz.; v. 6-7; N to E, variable.
4:26 p.m.	41 07	1.52	1.089	.820	.610	Same as at 3:05 p.m.
May 18:						
4:06 a.m.	44 55	1.74	1.236	.909	.722	Few clds.; hz. to 3°; W-3.
1:42 a.m.	59 45	1.16	1.366	.968	.760	Few clds.; hz. to 5°; v. 6-7; W-2.
0:52 p.m.	64 50	1.10	1.342	.939	.741	
2:16 p.m.	53 29	1.25	1.300	.937?	.730	Few Cunb in W; hz. to 6°; SW-3.
May 19:						
3:48 a.m.	37 22	1.64	1.157	.830	.662	Few Ci, Acu; hz. to 10°; v. 6-7; WSW-3.
4:42 p.m.	27 15	2.18	.886	.667	.520?	Few ACu; hz. to 15°; v. 7; SW-6.
May 22:						
3:37 a.m.	39 46	1.56	1.138	1.000	.781	1 Cist.; WNW-2.
2:53 a.m.	47 33	1.37	1.419	.996	.779	
May 24:						
3:40 a.m.	39 29	1.57	1.070?	.765?	.607	7 Cicu, Cist; d. hz. to 12°; v. 6; NW-3.
June 2:						
4:06 a.m.	35 39	1.71	1.160	.835	.685	Few Ci, Cicu, Cist; d. hz.; to 10°; v. 5-6; NW-2.
0:16 p.m.	69 42	1.06	1.454	1.019	.803	Few Ci in W; 1 Ci in S and SE; hz. to 6°; v. 9; NW-3.
2:02 p.m.	57 33	1.18	1.443	1.015	.796	Few Ci, Cist, Acu; hz. to 4°; v. 9; W-1.
4:05 p.m.	35 47	1.71	1.297	.933	.739	Few Ci in W; hz. to 3°; v. 9; W-SW-3.
June 3:						
5:33 a.m.	19 38	2.93	.967	.742	.611	Few clds.; hz. to 5°; v. 6-7; SW-5.
2:34 a.m.	52 14	1.27	1.204	.850	.670	5 Ci; hz.; v. 5-6; SW-5.
0:53 p.m.	67 14	1.09	1.278	.893	.696	Few Ci, Cist; hz.; v. 7; WSW-7.
2:04 p.m.	57 23	1.19	1.215	.857	.653	Few Cu; v. 7-8; WSW-7.
June 4:						
2:20 a.m.	54 56	1.22	1.239	.861	.677	2 Acu, Ast; lt. hz.; v. 7-8; NE-4-5.
0:26 a.m.	69 27	1.07	1.419	.965	.748	1 Cist; v. 8-9; NE-6.
2:53 p.m.	49 10	1.32	1.295	.913	.707	2 Ci, Cu; lt. hz. to 4°; v. 9; E-3.
June 7:						
0:48 a.m.	68 06	1.08	1.117	.783	.622	7 Acu, St cu, Cu; hz.; v. 6; S-2.
June 8:						
2:22 a.m.	54 38	1.23	1.186	.854	.666	Few Ci; Smk. hz., to 5°; v. 5-6; W-1.
1:40 a.m.	61 29	1.14	1.180	.825	.644	Few Ci, Cicu:, hz., smk.; WSW-2.
0:36 a.m.	69 15	1.07	1.213	.857	.670	Few Ci, Cicu; hz. to 7°; W-2.
0:30 p.m.	69 38	1.06	1.213	.838	.644	Few Ci, Cicu, Cist; hz., smk.; W-2.
June 9:						
3:04 a.m.	47 16	1.36	1.156	.818	.640	Few Cist in N; hz.; w 6-7; var.-1.
1:24 a.m.	64 04	1.11	1.215	.844	.657	Few Cicu; hz.; v. 6; SSE-2.
0:23 p.m.	70 08	1.06	1.234	.855	.661	Few clds.; hz. to 4°; v. 6-7.
2:56 p.m.	48 50	1.32	1.107	.785	.618	
4:16 p.m.	33 50	1.79	.943	.707	.553	4 Ci, Acu, Cunb; SSW-5.
June 10:						
1:30 a.m.	63 06	1.12	1.330	.920	.716	3 Ci, Cicu, Cist; lt. hz.; v. 9; WNW-5.
5:28 p.m.	26 56	2.20	1.020	.744	.596	4 Ci, Cicu, Cist; lt. hz.; v. 9; WNW-5.
5:50 p.m.	17 00	3.39	.907	.677	.546	
June 11:						
5:12 a.m.	24 16	2.42	.965	.707	.570	Few Ci; hz. in NW.; v. 7-8; NE-2.
3:27 a.m.	43 28	1.45	1.200	.828	.653	Few cld; hz. SWN; SE-2.
2:39 a.m.	51 56	1.27	1.334	.920	.720	Few cld; hz. in N and W; v. 9; SSW-3.
0:02 a.m.	70 53	1.06	1.351	.926	.729	Few Ci; lt. hz.; S-3.
1:12 p.m.	65 27	1.10	1.347	.926	.733	1 Ci, Cist; hz.; v. 9; SSW-4.
3:15 p.m.	45 28	1.40	1.269	.898	.711	Few Ci; lt. hz.; v. 9; SW-3.
3:22 p.m.	44 11	1.43	1.267	-------	.703	Few Ci; lt. hz.; v. 9; SW-4-5.
4:07 p.m.	35 42	1.71	1.208	.857	.683	
5:28 p.m.	19 11	3.02	.969	.742	.596	Few Ci, Cist, Acu; lt. hz.; SSW-6.
June 12:						
0:25 a.m.	70 17	1.06	1.158	.825	.635	1 Ci, Cist, Acu; WSW-4-5.
June 14:						
4:52 a.m.	27 37	2.15	1.069	.792	.642	Few Ci, Cist, Cicu; hz.; v. 9; NW-3.
3:18 a.m.	45 00	1.41	1.217	.870	.696	1 Ci, Cicu, Cist; v. 6-7; N-3.
2:57 a.m.	59 11	1.17	1.202	.872	.699	
June 15:						
5:33 a.m.	22 04	2.64	1.057	.812	.660	Few cld.; hz.; v. 9; NW-3.
2:49 a.m.	50 33	1.29	1.319	.922	.739	4 Cu; v. 9; NW-3.
June 18:						
5:34 a.m.	20 10	2.88	.996	.760	.620	2 Ci, Cist, Acu; v. 9; NW-4.
June 19:						
5:24 a.m.	21 58	2.65	.835	.651	.535	Few Cicu, Cist, Acu; v. 9; NW-6
June 20:						
0:49 a.m.	68 40	1.07	1.318	.943	.744	1 Ci, Cicu, Cist; NNE-1.
0:14 a.m.	71 01	1.06	1.403	.972	.770	1 Ci, Cicu, Cist; NNE.
0:14 p.m.	71 01	1.06	1.356	.939	.742	
June 22:						
2:14 a.m.	56 33	1.19	1.176	.811	.640	3 Ci, Cicu, Cist, Acu, fr. cu; hz.; v. 6-7; WNW-2.
1:38 a.m.	62 23	1.13	1.204	.825	.651	8 Ci, Cicu, Acu, Cu, fr. cu; WNW-5.
June 23:						
5:32 a.m.	20 31	2.84	1.024	.774	.633	1 Ci, Acu; hz.; v. 8; NW-5.
0:40 p.m.	69 31	1.06	1.436	1.011	.783	3 Ci, Cicu; v. 9; WNW-5.
0:55 p.m.	68 03	1.08	1.430	1.000	.783	
1:24 p.m.	64 25	1.11	1.414	0.983	0.781	
4:24 p.m.	32 57	1.84	1.215	.887	.705	Few Ci, Cist; lt. hz.; v. 9; NW-3.
5:38 p.m.	19 26	2.99	1.067	.833	.653	Few Cicu, St cu; WNW-5.
June 24:						
5:27 a.m.	21 35	2.70	1.087	.820	.661	Few Ci, St cu; hz.; N-1.
2:39 a.m.	52 21	1.26	1.221	.868	.685	Few Acu; d. hz. over Boston; S.&W.-2.
0:33 p.m.	70 03	1.06	1.206	.868	.694	2 Acu, Cu.
4:15 p.m.	34 36	1.76	1.042	.763	.624	Few Acu, thin Cist; SSW-6.
June 27:						
3:59 a.m.	37 23	1.64	.965	.711	.575	3 Cist, Cu; v. 5-6 W, NE, 6-7 S; S-3.
July 12:						
0:29 a.m.	68 52	1.07	1.244	.881	.731	Few Cu; hz.; v. 7-8; NE-4.
1:07 p.m.	65 23	1.10	1.290	.937	.764	Few Cu; v. 7-8; NE-4.
1:51 p.m.	59 14	1.17	1.244	.908	.739	
3:59 p.m.	36 41	1.67	1.103	.801	.636	Few Cu; v. 8-9; NE-5.
4:20 p.m.	32 48	1.84	1.046	.790	.627	Same as at 3:59 p.m.
5:17 p.m.	22 18	2.62	.901	.683	.583	Clds. same as at 3:59 p.m.; NE-4.
July 13:						
4:00 a.m.	36 25	1.68	1.005	.780	.628	Few Cicu; lt. E wind.
3:11 a.m.	45 24	1.40	1.169	.827	.671	V. 9; E-2.
1:40 a.m.	60 48	1.14	1.256	.857	.690	Few Cicu; E-2.
0:10 a.m.	69 30	1.06	1.277	.892	.712	Few Ci, few Cu; SSE-2.
0:50 p.m.	67 05	1.09	1.214	.849	.669	Same as at 0:10 a.m.; S-2.
2:10 p.m.	56 04	1.20	1.181	.822	.644	Few Cu; hz.; v. 7-8; S-E. variable.
3:43 p.m.	39 33	1.57	1.112	.800	.624	Few C; hz.; v. 7-8; SE-3.
5:23 p.m.	21 45	2.69	.993	.725	.575	Few Ci, Cu.
July 14:						
3:34 a.m.	41 13	1.52	1.182	.842	.666	Few Acu; SE.
3:03 a.m.	47 11	1.36	1.203	.854	.674	
1:30 a.m.	62 07	1.13	1.279	.888	.701	Same as at 3:34 a.m.
0:01 a.m.	69 27	1.07	1.314	.918	.712	Few Ci; E.
1:31 p.m.	62 02	1.13	1.320	.924	.733	Few Ci; ESE.
1:51 p.m.	59 00	1.17	1.302	.894	.707	
3:58 p.m.	36 41	1.67	1.163	.842	.668	Few Ci, Cu; ESE.
5:21 p.m.	21 27	2.72	.963	.733	.590	Few Ci, Cu.
July 18:						
2:42 a.m.	50 04	1.30	1.264	.893	.699	Few Ci; hz.; SW-2.
2:07 a.m.	55 49	1.20	1.286	.908	.707	
0:05 a.m.	68 47	1.07	1.366	.950	.729	Few Cu; v. 8; WSW-5-6.
3:43 p.m.	39 15	1.58	1.211	.871	.663	Few Ci, few Cu[illegible] SE; WSW-5-6
Aug. 6:						
0:34 a.m.	63 28	1.12	1.445	.990	.780	Few St, cu, fr. cu; lt. hz.; N-4.
1:35 p.m.	57 24	1.19	1.450	1.012	.780	4 Ci, 1, St, Cu; lt. hz; v. 9.
2:37 p.m.	47 56	1.34	1.378	.954	.740	2 Ci, St, Cu; lt. hz.; NE-3.
3:19 p.m.	40 39	1.53	1.307	.919	.716	Few Ci; v. 9.
Aug. 7:						
1:38 a.m.	56 43	1.19	1.338	.923	.718	3 Ci, Cist, St, Cu; lt. hz.; S-2.
Aug. 9:						
0:42 p.m.	62 09	1.13	1.369	.910?	.734	Few St, Cu; v. 9-10.
1:28 p.m.	57 35	1.18	1.365	.919	.736	Sky clear.
5:44 p.m.	13 30	4.22	.820	.629	.508	Sky clear; v. 9.
Aug. 11:						
1:50 a.m.	54 11	1.24	1.360	.923	.676	5 Acu, St, Cu; lt. hz.; v. 8.
0:05 p.m.	63 02	1.12	1.334	.917	.702	
Aug. 26:						
4:56 a.m.	18 43	3.10	1.070	.785	.620	Few Ci, Acu; lt. hz. and smk.; v. 9.
5:12 p.m.	15 50	3.63	.879	.669	.513	Cist, 5° from sun.
Aug. 27:						
1:28 p.m.	52 31	1.26	1.066	.772	.600	1 fr. cu, few Acu; d. hz.; v. 6-7; SW-4.
3:00 p.m.	39 17	1.58	1.102	.816	.642	
Aug. 30:						
3:51 a.m.	29 42	2.02	1.304	.939	.746	Few Ci; lt. hz.; v. 9; NW-2.
0:18 p.m.	56 33	1.19	1.387	.955	.755	Few Ci, fr. cu; lt. hz.; v. 9; NW-2.
1:11 p.m.	53 19	1.24	1.383	.966	.742	
3:04 p.m.	37 50	1.63	1.299	.922	.716	
4:03 p.m.	27 33	2.15	1.172	.852	.667	2 Ci, evaporating; v. 9; WNW-1.

TABLE 2.—*Weekly averages of daily totals of solar radiation received on a horizontal surface, as recorded at the Blue Hill Meteorological Observatory of Harvard University, Milton, Mass.*

Week beginning	Gr. cal.	Week beginning	Gr. cal.
Dec. 10, 1932	119	Apr. 23, 1933	470
Dec. 17, 1932	146	Apr. 30, 1933	551
Dec. 24, 1932	89	May 7 1933	498
Jan. 1, 1933	168	May 14, 1933	615
Jan. 8, 1933	129	May 21, 1933	506
Jan. 15, 1933	174	May 28, 1933	426
Jan. 22, 1933	123	June 4, 1933	573
Jan. 29, 1933	217	June 11, 1933	453
Feb. 5, 1933	217	June 18, 1933	558
Feb. 12, 1933	242	June 25, 1933	516
Feb. 19, 1933	253	July 2, 1933	422
Feb. 26, 1933	201	July 9, 1933	509
Mar. 5, 1933	341	July 16, 1933	433
Mar. 12, 1933	302	July 23, 1933	495
Mar. 19, 1933	309	July 30, 1933	540
Mar. 26, 1933	377	Aug. 6, 1933	527
Apr. 2, 1933	256	Aug. 13, 1933	349
Apr. 9, 1933	313	Aug. 20, 1933	269
Apr. 16, 1933	383	Aug. 27, 1933	451

NOTE.—In any week in which the record for 1 or more days is incomplete, the sum of the averages for each hour has been adopted as the average daily total for that week.

WHAT IS THE EFFECT OF HEAVY RAINS WITH HIGH WINDS ON THE RUN OF CUP-WHEEL ANEMOMETERS?

By CHARLES F. MARVIN

[Weather Bureau, Washington, September 1933]

Inquiry has been received as to the possible effect on the indications by cup anemometers of wind velocities due to the bombardment of rain drops under conditions of comparatively high winds and very heavy rains.

This is an interesting question which has perhaps not been very carefully investigated experimentally. Nevertheless, a seemingly conclusive answer is possible on analytical grounds.

Two obvious effects require consideration. First, the cups become thoroughly wetted by the addition of a certain amount of water and therefore slightly heavier. The second effect arises from the collisions with numerous water drops striking against both the concave and convex faces of the cups.

By measurement it is found that the actual weight of water on any of the cup wheels of the Weather Bureau anemometers amounts to 6.1 grams, which is 2.2 percent of the weight of the standard light-weight cups and, of course, a still smaller percentage of that of the heavier cup systems. Wind-tunnel tests with steady wind velocities show conclusively that when the length of the arms and other dimensions are the same the run of these anemometers is wholly independent of small changes in the mere weight of the cups. In the case of gusty winds the lag of the anemometer in following the wind is, of course, greater the greater the weight of the cups. For this reason heavy rain tends to make the cups lag behind the true wind velocity more than they do in the same wind without rain, and conversely when the wind velocity is falling off rapidly the cups overrun slightly. These effects are quite inconsequential on the average run of the cups. In other words, the effect of the increased weight of the cups due to rainfall may be regarded as negligible and unimportant.

As to the effect of the bombardment of the cups by the raindrops, reasoning indicates that the convex cups which are advancing in the wind collide with the raindrops at relatively high velocities. We are thinking here of the horizontal component of the motion of the raindrops with reference to the surfaces of the cups at the instant of collision. The concave cups, however, are advancing *with* the wind and the kinetic energy involved in the collision of the raindrops and these cups because of the smaller relative velocities is certainly much less than the corresponding kinetic energies involved in the collisions of the raindrops with the convex cups. The ultimate result of these collisions must therefore be a tendency to retard the speed of rotation of the cups. As already stated, no wind tunnel or other measurements are availble by which the amount of this retardation can be evaluated.

On the other hand, we do have carefully made measurements of the effects of moderate degrees of friction in retarding the motion of the cups as compared to the almost complete absence of friction. These friction tests show that even quite appreciable amounts of friction have an inappreciable or very small effect in retarding the speed of the cups in high winds and it is certain that the effects of the bombardment of the raindrops is quite appreciably less than the moderate amounts of friction which have been subjected to tests.

The final conclusions of the foregoing analysis are therefore (1) that rain tends to make the anemometer more sluggish by a very small amount in responding to fluctuating gusty winds, although the average run of the cups in such gusty winds is not appreciably affected and (2) that heavy rains in high winds retard the run of the cups substantially as does friction, but that the amount of this retardation, while not exactly known, certainly is inconsequential and unimportant.

We may conclude this consideration by asking how the cups would behave if exposed in perfectly still air during a heavy downpour of rain. A little analysis indicates that the action of the rain on each one of the cups would tend more or less to turn it backward. The combined force on all the cups might even be sufficient to actually turn a nearly frictionless anemometer cup wheel backward. In this way, too, falling rain tends to oppose motions caused by the wind.

TROPICAL DISTURBANCES OF AUGUST 1933

By R. HANSON WEIGHTMAN

[Weather Bureau, Washington, D.C., September 1933]

The number of tropical disturbances this month was unusually large, 7 disturbances being reported, 4 of which were of slight intensity and 3 of hurricane intensity.

August 12–20.—The first disturbance of the month made its appearance in the region of Barbadoes, West Indies, whence it moved first west-northwest, passing south of Jamaica, then northwestward over Grand Cayman, thence more to the northward over extreme western Cuba, and finally northward to a point off the northwestern Florida coast where it lost intensity. The few reports availble would indicate that the winds of this storm may have reached gale force while its center was south of Jamaica; otherwise, it was of minor consequence. Heavy rains attending thunderstorms, caused damaging floods in eastern Jamaica.

August 16–21.—A disturbance of slight intensity appeared over the Windward Islands on the 16th and moved westward. It was last traceable about 300 miles east of the Honduras coast on the 21st.

August 17–26.—This disturbance originated some distance to the east of the Windward Islands. It was first located from telegraphic reports on the morning of the 18th, about 900 miles east of Puerto Rico. The S.S. *Western Prince* in latitude 19°30′ N., longitude 51° W., reported barometer 29.76 inches, wind northeast 42 m.p.h. with heavy southeast swell. It moved westward until the 18th, then followed a course northwest by north until the 21st, when it was central about 150 miles southwest of Bermuda, a maximum wind velocity of 64 miles from the east being reported at St. Georges. During the next 24 hours it bore more to the westward, with somewhat decreased speed and then turned to the northwest, passing nearly over but slightly to the east of Cape Hatteras, with lowest barometer 28.67 inches and maximum wind velocity 64 m.p.h. from the northeast. When the disturbance was about 150 miles southwest of Bermuda on the morning of the 21st, storm warnings were ordered between Cape Hatteras and Boston, with the information

that the tropical disturbance was of great intensity. On the morning of the 22d, these storm warnings were continued with the following information:

Tropical disturbance attended by fresh to strong gales, central about 350 miles southwest of Bermuda and same distance southeast of Cape Hatteras, direction of movement uncertain but probably will remain nearly stationary next 12 hours. Strong northeast winds probably reaching gale force off the coast.

At 4 p.m. of the 22d, storm warnings were extended south of Cape Hatteras to Southport, N.C. On the evening of the 22d, the following bulletin was issued:

Atlantic coast disturbances central about 150 miles southeast of Cape Hatteras, moving slightly north of west. Center will cross southern coast of North Carolina early Wednesday forenoon, preceded by dangerous shifting gales tonight between Virginia Capes and Southport, N.C. Advise all interests.

On the morning of the 23d the center was a few miles south of Norfolk, Va., where the pressure was 28.84 inches. It passed over Norfolk with lowest pressure 28.68 inches at 9:20 a.m. and a maximum wind velocity of 56 miles, while Cape Henry had a maximum velocity of 68 m.p.h. The center was near Washington, D.C., that evening, with a pressure of 28.94 inches. It moved northward to central Pennsylvania with decreasing intensity and then turned northeastward down the St. Lawrence Valley with further decrease in intensity.

This was one of the most severe storms that has ever visited the Middle Atlantic coast. It caused great damage in northeastern North Carolina, central and eastern Virginia, and in Maryland, Delaware, and portions of New Jersey, due to severe gales and high tides, largely the latter. While hurricane velocities were not actually recorded at any Weather Bureau station, it seems quite probable that along the coast between Delaware Breakwater and Cape Hatteras winds may have reached the lower limits of hurricane force (75 m.p.h.) for short intervals. Warnings of high tides for the Norfolk area were given out preliminarily as early as the 21st and more specifically and positively during the afternoon and evening of the 22d. A tide of 7 feet above normal occurred, flooding the downtown business section of Norfolk as never before. The official in charge at Norfolk reports that plate-glass windows were broken in the business section by the wind, and states that:

Loss to shipping in this remarkably severe storm, which has been characterized as the worst ever experienced in this section, was practically negligible. The warnings were so widely disseminated that vessels stayed in port, or sought shelter if at sea, except in 1 or 2 cases. * * *

A great deal of damage resulted to resorts on the Virginia, Maryland, Delaware, and New Jersey coasts and also in Chesapeake Bay. Power, telephone, and telegraph services were disrupted for a time in portions of Delaware southward to Cape Charles. An extract from the report of the Weather Bureau official at Baltimore, gives details regarding the extent of the damage in the State of Maryland:

The damage to property, exclusive of crops, is estimated to be in excess of $10,000,000, and to crops about $7,000,000. Crop damage in Maryland alone, estimated by the State Experiment Service of the University of Maryland, from the reports of county agents, was as follows: Tobacco crop, more than $1,500,000 (Baltimore tobacco experts estimate $2,000,000, including stocks in warehouses); tomatoes somewhat more than $1,000,000; corn crop, including loss of fodder, more than $2,000,000. Worcester County suffered the most damage to the corn crop $300,000. The least was $6,000 in Allegany County.

The fisheries industry was injured severely, the amount being difficult to estimate but probably around $3,000,000. Many boats were destroyed and a larger number sunk and damaged, buildings and wharves were wrecked, etc. At Crisfield, Md., alone, the damage to the industry was $100,000. The damage to highways was $406,851 in Maryland and $150,000 in Delaware. Railroads suffered a property loss of about $555,000; telephone and electric companies about $364,000; Federal buildings and works probably about $1,100,000 (Naval Academy at Annapolis alone $90,000); passenger, freight, and pleasure boats and establishments about $392,000 (Maryland Yacht Club at Baltimore in excess of $60,000); miscellaneous damage to dwellings, pleasure resorts, coast towns, etc., about $2,000,000; shore land lost in Maryland by wave action (estimated by State conservation commissioner) about 2 square miles; in Delaware about 1 square mile.

August 24–30.—A disturbance of slight intensity first appeared on the 24th, central apparently about 340 miles north by east of Antigua, West Indies. It moved northwestward during the following 2 days, then recurved to the northward and passed about 160 miles west of Bermuda during the night of the 27th. By the morning of the 30th it was central about 250 miles south of Cape Race, Newfoundland, moving northeastward.

August 27–29.—A disturbance of slight intensity developed in a region of unsettled weather over Mexico near Frontera during the 26th and 27th. From vessel reports subsequently received, it apparently moved northwestward to the vicinity of Tampico by the 28th attended by heavy rains at Mexican coast stations but without strong winds. By the evening of the 28th, available vessel observations over the northwestern Gulf showed that the wind velocities had increased to 22 m.p.h., and shifted from northeast and east to southeast. Consequently, on the morning of the 29th, with the uncertainty regarding the advance of the center northward, storm warnings were ordered from Port Arthur to Corpus Christi, as follows:

Tropical disturbance of slight intensity about 125 miles southeast of Corpus Christi apparently moving northward; will cause fresh to strong northeast winds late this afternoon and tonight, with strong shifting winds over very small area around center.

Special observations received during the afternoon of the 29th showed rather definitely that the center was south of Brownsville and at 9 p.m. storm warnings were ordered down.

August 28–September 6.—This disturbance first appeared the evening of the 28th, a short distance northeast of the Windward Islands. By the morning of the 29th, ship reports showed that it was attended by gales and moving west or west-northwest. It continued to move west by north, passing slightly north of Turks Islands with lowest barometric pressure at Grand Turk of 29.41 inches at 3 p.m., of the 30th, and maximum wind of 56 miles from the southwest. By the following morning its center was a short distance southwest of Crooked Island, Bahamas, and 24 hours later near Sagua la Grande on the north coast of Cuba, attended by winds of hurricane force.

On the evening of the 30th, storm warnings were ordered for southern Florida.

During the late afternoon of September 1, the barometer at Habana read 28.92 inches as the storm center passed a short distance north of the city. The highest wind velocity at Habana was 94 m.p.h. from the south, while at Key West, Fla., the maximum was 42 m.p.h. from the east. Little damage was done at Key West, but, according to press reports there was considerable loss of life and much property damage along the north coast of Cuba and probably also some distance inland.

Moving westnorthwestward across the Gulf of Mexico, the storm center reached the ninety-fifth meridian, approximately 150 miles east of Brownsville, Tex., the morning of September 4, after which it moved directly westward, and passed inland just north of Brownsville

the following night. Brownsville reported a barometer reading of 28.02 inches at 1:30 a.m. of the 5th, and an estimated maximum wind of 80 m.p.h. from the northwest earlier in the night. According to an Associated Press dispatch from Brownsville there were 22 known deaths and property damage running into millions of dollars in the area from Corpus Christi to some distance south of Brownsville in extreme northeastern Mexico. However, no lives were lost in either Brownsville or Corpus Christi. The remarkable escape of Brownsville citizens was attributed to the fact that all had ample warning that the tropical hurricane was approaching the city.

Realizing that the storm was a major hurricane and that the week-end holiday would extend over Labor Day, the district forecaster sent the following warning to all Texas coast stations on the morning of Saturday, September 2:

> Uncertain where tropical storm in Gulf will reach coast line, but all persons should be warned to remain away from inaccessible places on Texas coast over week end.

That the warning was heeded was attested by the following excerpt from the report of the official in charge, Corpus Christi, Texas:

> * * * Probably never before in the history of Texas hurricanes have such widespread and early warnings been given as were received from Washington in advance of this one. The telegram of Saturday, September 2, warning all persons to avoid inaccessible places over the week end probably saved thousands of lives. Major Swan, owner of the Don Patricio Causeway, estimated that between 2,500 and 4,000 visitors would have passed over the causeway to Padre Island during Sunday and Monday had it not been for the timely warning sent out from the central office. The same is true of Mustang Island, Bird Island, and the many other places north and south of this city. It is not an exaggerated estimate to state that between 6,000 and 10,000 persons might have been in inaccessible places had it not been for the advance warning to stay away from those places. * * *

At 10 p.m. of September 3, hurricane warnings were ordered displayed from Corpus Christi to Freeport and storm warnings on the remainder of the Texas coast. The storm at this time was central about 300 miles due east of Brownsville and still moving west-northwestward. No reports were received from the vicinity of the storm the morning of the 4th, but when it became apparent during the late afternoon and evening that the storm was moving directly westward and would reach the coast not far north of Brownsville, hurricane warnings were ordered south of Corpus Christi to Brownsville, while the hurricane warnings north of Corpus Christi were changed to storm warnings.

August 31–September 5.—On the morning of the 31st, another tropical disturbance was about 225 miles north-northeast of Antigua, West Indies. It subsequently passed over Florida. An account of this disturbance will appear in the September issue of the Monthly Weather Review.

BIBLIOGRAPHY

C. Fitzhugh Talman, in charge of library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Denmark. Danske meteorologiske institut
Danmarks klima belyst ved tabeller og kort. Kobenhavn. 1933. 266 p. 40 pl., tables. 25½ cm.

Goujon, G.
Les relations entre la végétation française et le climat. Paris. 1932. 186 p. maps. 33 cm. (Mem. de l'Off. nat. mét. de France.)

Great Britain. Meteorological office
A barometer manual for the use of seamen: a text book of marine meteorology. With an introduction and appendices. 11th ed. London. 1932. 94 p. illus., charts, tables, diagrs., plates. 24½ cm. ([Publications] official 61.) (Air ministry. Meteorological office.)

Hoyt, W. G., & Troxell, H. C.
Forests and stream flow. p. 1037–1066. tables, diagrs. 23 cm. (Excerpt American society of civil engineers. Proceedings. v. 58, no. 6. August 1932.)

Jameson, H.
On the expectancy of heavy rainfall in Ceylon. Colombo. 1932. 13 p. plates, charts. 21 cm. (Transactions of the Engineering association of Ceylon.)

Jaumotte, J.
Passage sur la Belgique d'un cyclone à secteur chaud. 2. La compensation thermique des baromètres anéroides. 3. L'orage du 12 juin 1929. (Repr.: Association française pour l'avancement des sciences. Congrès de Bruxelles 25 au 30 juillet 1932.) Paris. 1932. p. 163–173. figs. 24 cm.

Jones, Inigo
Seasonal forecasting. Brisbane. 1932. 16 p. 23 cm.

Kupfer, Egon
Die Frühlingsregen im Gebiet des Mittelmeerklimas. Jena. 1932. 50 p. maps (fold.). 21 cm. (Mitteilingen der Thüringischen Landeswetterwarte. Heft 5.)

Linke, F.
Meteorologisches Taschenbuch. II. Zweite Ausgabe . . . Leipzig. 1933. xii, 336 p. figs. 21½ cm.

Lugeon, Jean
Notice préliminaire sur l'expédition nationale polonaise de l'année polaire 1932–1933 à l'île des Ours. Warszawa. 1933. 47 p. plates, map, plans. 24 cm. (Extrait du "Bulletin de la Société géophysique de Varsovie." Fasc. no. 7–8. 1933.)

Maughan, William E.
Climatic conditions of state. Montana has two distinct climates separated by the continental divide; extremes of temperature vary greatly according to altitude. Helena. 1933. p. 15–19. illus., tables. 23 cm. (Excerpted from Montana. v. 7, no. 4, May 1933.)

Navarro Neumann, Manuel M[ari]a S.
El Professor Luis Palazzo. (Repr. Ibérica, 22 julio 1933.) Barcelona. 1933. p. 72–73. port. 29 cm.

Plummer, F. E.
Aspects of rainfall in the Western Cape Province. A basis for geographical and agricultural study. Pretoria. 1932. 80 p. tables. 25½ cm. (University of Pretoria. Series no. 1, 22.)

Queensland. Bureau of seasonal forecasting
Tables of rainfalls in Queensland. (Being a monthly and yearly summary of rainfalls registered by 159 recording stations throughout Queensland over the whole period during which records have been kept.) Prepared by Inigo Jones. Brisbane. 1933. 168 p. tables. 25 cm.

San Sebastián. Observ. de Igueldo
Cinquenta y cinco años de observaciones pluviométricas en San Sebastián (1878–1932). San Sebastián. 1933. 29 p. tables (some fold.). 22 cm. (Trabajos del Observatorio de Igueldo (San Sebastián). Publicación núm. 6.)

Scaëtta, H.
Les famines périodiques dans le Ruanda. Contribution à l'étude des aspects biologiques du phénomène. (Note préliminaire.) 42 p. pls., tables, diagrs. 29 cm. (Inst. royal colonial belge. Sections des sc. natur. et méd. Mémoires. Tome 1. fasc. 4.)

Schinze, Gerhart
Untersuchungen zur aerologischen Synoptik. Hamburg. 1932. p. D 1–D 44. tables, charts. 24 cm.

Smolăr, Văclav
Mêrêni teploty vzduchu při zkouškách za letu. (Détermination de la température de l'air pendant les essais en vol.) Praha. 1932. 38 p. tables. 30 cm. (Zprávy vojenského leteckého ústavu studijního v Praze. Ročník 6. Číslo 1o.)

Soreau, Rodolphe
L'air moyen et le stratosphère. Congrès du génie civil (23–29 septembre 1931). Paris et Liége. 1932. 128 p. illus. (chart) diagrs. 24 cm.

Størmer, Carl
Height and velocity of luminous night clouds observed in Norway 1932. Oslo. 1933. 47 p. lo pl., figs. 23 cm. (University observatory, Oslo. Publication no. 6.)

Takeda, K., and others
Monthly and annual deviations of meteorological elements in Japan. Tokyo. 1933. p. 211–364. tables, pl., diagrs. 26 cm. (Journal of the faculty of science, Imper. univ. of Tokyo. Section 1. Mathematics, astronomy, physics. chemistry. v. 2, Part 8.) (Contribution 13 from the Geophysical seminary in the Physical institute. Prof. S. Fujiwhara.)

Wallén, Axel
Till kännedomen om klimatet i skogen och andra växtsamhällen. (De la connaissance du climat des forêts et d'autres associations végétales.) Stockholm. 1932. p. 375–401. illus., tables, diagrs. 24½ cm. (Särtryck ur Svenska skogsvårdföreningens tidskrift 1932, Häfte III–IV.)

White, George V.
The great storm of September 16 and 17, 1932. [1933.] p. 164–183. maps, tables. 23½ cm. (Repr. Journal of the New England water works assn., v. 17, no. 2.)

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING AUGUST 1933

By IRVING F. HAND, Assistant in Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January 1932, REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged above normal for August at all Weather Bureau stations where normal incidence measurements were made.

Table 2 shows an excess in the total radiation received on a horizontal surface at all stations except Pittsburgh and Twin Falls.

Table 3 shows slightly diminished turbidity for the month as a whole.

Polarization measurements obtained at Washington on 4 days give a mean of 57 percent with a maximum of 60 percent on the 5th. At Madison, observations on 11 days give a mean of 63 percent with a maximum of 74 percent on the 4th. The maximum at Madison is considerably above normal; the other values are close to normal.

TABLE 1.—*Solar radiation intensities during August 1933*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D.C.

Date	8 a.m. 75th mer. time	Sun's zenith distance 78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon Local mean solar time
		Air mass A.M.					P.M.				
	e.	5.0	4.0	3.0	2.0	1.0 [1]	2.0	3.0	4.0	5.0	e.
	mm	cal	cal	cal	cal	cal	cal	cal	cal	cal	mm
Aug. 2	20.57			0.78	0.98	1.30					17.96
Aug. 5	10.97		0.90	1.01	1.13	1.37					9.14
Aug. 7	14.10					1.23					12.24
Aug. 15	12.24				.90						9.47
Aug. 25	15.65	0.70	.83	.91	1.10	1.41	1.10				16.20
Aug. 30	10.59	.65	.83	.85	1.16						10.59
Means		(.68)	.85	.89	1.05	1.33	(1.10)				
Departures		+.05	+.16	+.13	+.12	+.10	+.07				

TABLE 1.—*Solar radiation intensities during August 1933*—Con.

[Gram-calories per minute per square centimeter of normal surface]

MADISON, WIS.

Date	8 a.m. 75th mer. time	Sun's zenith distance 78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon Local mean solar time
		Air mass A.M.					P.M.				
	e.	5.0	4.0	3.0	2.0	1.0 [1]	2.0	3.0	4.0	5.0	e.
	mm	cal	cal	cal	cal	cal	cal	cal	cal	cal	cal
Aug. 1	16.79					1.40					9.83
Aug. 3	12.68					1.47					7.04
Aug. 4	10.59	0.89	0.99	1.11	1.27	1.49	1.18				8.81
Aug. 5	9.83		.88	1.01	1.18	1.41					7.87
Aug. 8	11.81			.78	.98	1.40					11.79
Aug. 11	15.65				1.05	1.42					10.97
Aug. 12	13.61	.66	.79	.97	1.08	1.28					12.68
Aug. 14	7.57	.79	.89	1.06	1.20	1.44					7.87
Aug. 15	8.48	.73	.86	1.03	1.23	1.43					9.14
Aug. 17	14.10				1.13	1.40					12.24
Aug. 18	10.59		.94								7.87
Aug. 19	9.14	1.03	1.12	1.19	1.23	1.40					7.29
Aug. 26	10.97			.81	.96	1.31					9.83
Aug. 28	10.59		.86	.99	1.16	1.44					8.18
Aug. 31	10.97					1.25					8.18
Means		.82	.92	.99	1.14	1.40	(1.18)				
Departures		+.04	+.08	+.05	+.04	+.08	+.10				

LINCOLN, NEBR.

Date	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
Aug. 10	17.37								0.79	0.68	19.23
Aug. 11	12.24		0.90	1.00	1.16	1.46	1.14	0.95			10.97
Aug. 14	10.21							.91	.82	.66	14.10
Aug. 17	11.81		.88	1.02		1.36	1.16	.96	.86	.75	10.21
Aug. 18	7.87		.83								11.81
Aug. 24	15.65		.78	.91							13.13
Aug. 25	11.81		.96	1.08	1.24	1.45					11.38
Aug. 30	10.97			.94	1.12	1.31	1.14	.95	.78	.68	9.83
Aug. 31	10.97				1.09	1.27	1.10	.90	.72	.60	12.24
Means			.87	.99	1.15	1.37	1.16	.93	.79	.67	
Departures			+.09	+.08	+.06	+.06	+.08	+.05	+.03	−.02	

BLUE HILL, MASS.

Date	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
Aug. 2	19.9						0.98				19.2
Aug. 6	9.1						1.18	0.95			7.9
Aug. 9	11.4						1.02	.98	0.86		11.4
Aug. 15	11.4						1.08	.91			11.4
Aug. 26	13.6			1.08	1.20	1.46	1.16	.97	.87	0.69	14.6
Aug. 27	16.8						1.05	.82	.58	.48	15.1
Aug. 30	10.2				1.32	1.47	1.22	1.09	.87	.79	9.5
Means				(1.08)	1.26	1.46	1.10	.95	.80	.65	

[1] Extrapolated.

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Pittsburgh	Fairbanks	Twin Falls	La Jolla	Gainesville	Miami	New Orleans	Riverside
	Gram calories per square centimeter													
1933	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
July 30	585	501	417	444	476	691	421	411	596	381	366	408	459	645
Aug. 6	476	469	468	438	438	661	403	280	586	364	505	563	345	558
Aug. 13	451	531	503	519	335	619	452	301	527	394	338	370	276	594
Aug. 20	306	495	365	458	242	618	359	334	565	431	407	493	443	517
Aug. 27	406	449	462	425	419	586	313	288	545	483	----------	490	343	530
	Departures from weekly normals													
July 30	+120	+37	+91	+54	+78	+63	−35	----------	+13	−16	−58	−127	----------	----------
Aug. 6	+30	+10	+24	+64	+70	+47	−19	----------	−8	−3	+93	+42	----------	----------
Aug. 13	+15	+86	−18	+134	−7	+25	+56	----------	−61	+20	−81	−135	----------	----------
Aug. 20	−103	+55	+120	+101	−82	+49	+3	----------	−4	+37	+21	−4	----------	----------
Aug. 27	−11	−34	−6	−68	+91	+47	−24	----------	−1	+105	----------	+5	----------	----------
	Accumulated departures on Sept. 2													
	+7,182	−2,422	+3,990	+12,397	+8,666	+7,098	+203	----------	−147	+8,939	----------	−4,802	----------	----------

TABLE 3.—*Solar radiation measurements, and determinations of atmospheric-turbidity factor, β, Washington, D.C., August 1933*

[Values in italics have been interpolated]

Date and solar-hour angle	Solar altitude, *h*.	Air mass, *m*.	I_m	I_y	I_r	β	Blueness of sky	Atmospheric dust particles per cubic centimeter	Notes: Skylight polarization, P., clouds, etc.
Aug. 2			gr. cal.	gr. cal.	gr. cal.				
0:39a	67–25	1.09	1.242	0.881	0.661	0.138	5	712	P=51.8%
0:35a	67–31	1.09	1.254	.885	.666	.135			
Aug. 5									
4:45a	25–01	2.37	1.082	.808	.628	.068		428	
4:42a	25–36	2.31	1.075	.809	.631	.070			
4:20a	29–51	2.01	1.123	.838	.654	.080	6		P=60.0%
4:16a	30–38	1.96	1.116	.841	.657	.090			
2:24a	51–46	1.27	1.276	.941	.714	.125			
2:19a	52–32	1.26	1.264	.947	.714	.140			
Aug. 7									
3:26a	40–00	1.55	1.108	.862	.648	.070		296	
3:19a	41–18	1.51	1.139	.868	.652	.060			
Aug. 25									
5:14a	15–39	3.68	.862	.652	.523	.060		376	
5:11a	16–14	3.55	.875	.657	.526	.060			
4:49a	20–32	2.84	.959	.714	.557	.065			
4:43a	21–40	2.69	.990	.717	.560	.065			
4:14a	27–20	2.17	1.035	.805	.623	[1].105			
4:05a	28–59	2.06	1.099	.812	.628	.080	6		P=59.6%
3:13a	38–47	1.60	1.250	.856	.646	.050			
3:09a	39–31	1.57	1.245	.860	.651	.060			
0:44a	60–12	1.15	1.318	.912	.699	.095			
0:41a	60–18	1.15	1.326	.917	.701	.090			
Aug. 30									
4:57a	17–54	3.23	.832	.673	.567	.125		498	
4:54a	18–26	3.14	.835	.676	.571	.120			
4:47a	19–50	2.93	.961	.708	.581	.070			
4:44a	20–24	2.85	.978	.711	.584	.070			
4:06a	27–45	2.14	1.105	.805	.635	.070			
4:03a	28–17	2.10	1.129	.809	.639	.065	6		P=59.8%

[1] Incipient cloudiness.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic: Diff. long.	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day
1933	h m	°	°	°			
Aug. 1 (Naval Observatory)	13 14	No spots			------	------	------
Aug. 2 (Naval Observatory)	11 22	+27.0	161.4	−15.0	------	22	22
Aug. 3 (Naval Observatory)	13 40	No spots			------	------	------
Aug. 4 (Naval Observatory)	14 22	No spots			------	------	------
Aug. 5 (Naval Observatory)	10 21	No spots			------	------	------
Aug. 6 (Naval Observatory)	11 21	No spots			------	------	------
Aug. 7 (Naval Observatory)	11 39	No spots			------	------	------

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic: Diff. long.	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day
	h m	°	°	°			
Aug. 8 (Naval Observatory)	11 46	No spots			------	------	------
Aug. 9 (Naval Observatory)	10 54	No spots			------	------	------
Aug. 10 (Mount Wilson)	8 58	No spots			------	------	------
Aug. 11 (Mount Wilson)	8 48	No spots			------	------	------
Aug. 12 (Naval Observatory)	10 38	No spots			------	------	------
Aug. 13 (Naval Observatory)	12 30	No spots			------	------	------
Aug. 14 (Naval Observatory)	14 42	No spots			------	------	------
Aug. 15 (Naval Observatory)	11 8	No spots			------	------	------
Aug. 16 (Mount Wilson)	9 55	+15.0	325.0	+10.0	2	------	2
Aug. 17 (Naval Observatory)	12 53	No spots			------	------	------
Aug. 18 (Naval Observatory)	12 54	No spots			------	------	------
Aug. 19 (Naval Observatory)	14 1	------	------	------	------	------	------
Aug. 20 (Mount Wilson)	9 25	No spots			------	------	------
Aug. 21 (Mount Wilson)	9 25	No spots			------	------	------
Aug. 22 (Mount Wilson)	9 19	No spots			------	------	------
Aug. 23 (Mount Wilson)	11 22	No spots			------	------	------
Aug. 24 (Naval Observatory)	13 35	No spots			------	------	------
Aug. 25 (Naval Observatory)	11 8	No spots			------	------	------
Aug. 26 (Naval Observatory)	11 20	No spots			------	------	------
Aug. 27 (Naval Observatory)	10 51	No spots			------	------	------
Aug. 28 (Naval Observatory)	12 55	No spots			------	------	------
Aug. 29 (Naval Observatory)	11 19	No spots			------	------	------
Aug. 30 (Naval Observatory)	14 25	No spots			------	------	------
Aug. 31 (Mount Wilson)	9 20	No spots			------	------	------
Mean daily area for August	------	------	------	------	------	------	1

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR AUGUST 1933

(Dependent alone on observations at Zurich and its station at Arosa)

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

August 1933	Relative numbers	August 1933	Relative numbers	August 1933	Relative numbers
1	0	11	0	21	0
2	0	12	7	22	0
3	0	13	0	23	0
4	0	14	0	24	0
5	0	15	0	25	0
6	0	16	0	26	0
7	0	17	0	27	0
8	0	18	0	28	0
9	0	19	0	29	0
10	0	20	0	30	0
				31	0

Mean: 31 days=0.2.

AEROLOGICAL OBSERVATIONS

[Aerological Division, W. R. Gregg, in charge]

By L. T. Samuels

August free-air temperatures were moderately below normal at the coast and border stations and moderately above at the interior stations. (See table 1.) At most places the relative humidity departures were of opposite sign to those of temperature.

Resultant free-air wind directions for the month did not deviate greatly from the normals. (See table 2.) Resultant free-air wind velocities generally were below normal at the northern stations and above normal at the southern.

Table 1.—*Free-air temperatures and relative humidities obtained by airplanes during August 1933*

TEMPERATURE (°C.)

Altitude (meters) m.s.l.	Cleveland, Ohio (246 meters)[1]		Dallas, Tex. (146 meters)[2]		Norfolk, Va. (3 meters)[3]		Omaha, Nebr. (300 meters)[4]		Pembina, N.Dak. (254 meters)[5]		Pensacola, Fla. (2 meters)[3]		San Diego, Calif. (9 meters)[3]		Washington, D.C. (2 meters)[3]	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	17.7	[6]	24.1	[6]	24.5	−0.2	18.4	[6]	14.8	[6]	25.7	+0.1	20.6	−1.3	22.5	−0.9
500	20.3	[6]	25.4	[6]	22.2	−1.0	19.6	[6]	17.3	[6]	23.5	−0.5	17.3	−2.5	21.9	0.0
1,000	18.3	+0.3	23.5	+1.0	19.6	−1.3	20.6	+0.3	16.0	−1.0	20.6	−0.7	21.1	−2.1	20.2	+0.4
1,500	15.3	+0.3	20.3	+0.6			17.9	+0.1	13.0	−1.5						
2,000	12.3	+0.2	17.4	+0.8	13.7	−0.8	14.6	−0.2	10.1	−1.8	14.2	−0.9	20.0	−0.8	13.9	0.0
2,500	9.7	+0.4	14.5	+1.0			12.2	+0.6	7.1	−1.9						
3,000	7.9	+1.5	11.7	+1.0	9.2	+0.2	9.4	+1.2	4.7	−1.5	7.9	−1.4	13.3	−0.8	9.4	+1.2
4,000	3.4	+2.1	6.0	+0.7			2.7	+1.1	−1.1	−1.9	1.7	−1.7	6.4	−0.8	4.8	+2.2
5,000	−1.8	+1.9	0.5	+0.9			−3.6	+0.9	−7.6	−3.1	−3.9	−1.7				

RELATIVE HUMIDITY (PERCENT)

Altitude (meters) m.s.l.	Cleveland Mean	Departure	Dallas Mean	Departure	Norfolk Mean	Departure	Omaha Mean	Departure	Pembina Mean	Departure	Pensacola Mean	Departure	San Diego Mean	Departure	Washington Mean	Departure
Surface	81	[6]	86	[6]	81	+5	85	[6]	74	[6]	85	0	76	+1	84	+10
500	65	[6]	70	[6]	76	+9	73	[6]	68	[6]	78	+1	84	+9	73	+6
1,000	64	−1	67	+7	69	+6	57	−3	66	+8	76	+1	57	+11	69	+6
1,500	67	+3	70	+12			58	0	66	+10						
2,000	65	+4	68	+10	64	+1	60	+2	66	+12	70	+1	36	+2	75	+9
2,500	57	0	61	+5			52	−5	64	+11						
3,000	47	−7	55	+3	52	−7	47	−10	57	+4	66	+3	39	+4	59	0
4,000	38	−8	57	+18			46	−6	52	+3	65	+2	40	+4	53	−3
5,000	33	+1	64	+35			43	−10	42	−4	57	+1				

Weather Bureau observations made near 5 a.m.; Navy observations near 7 a.m., E.S.T.

[1] Temperature and humidity departures based on normals of Royal Center, Ind.

[2] Temperature departures based on normals determined by interpolating latitudinally between those of Groesbeck, Tex., and Broken Arrow, Okla. Humidity departures based on normals of Groesbeck, Tex.

[3] Naval air stations.

[4] Temperature and humidity departures based on normals of Drexel, Nebr.

[5] Temperature departures based on normals determined by extrapolating latitudinally those of Ellendale, N.Dak., and Drexel, Nebr. Humidity departures based on those of Ellendale, N.Dak.

[6] Surface and 500-meter level departures omitted because of difference in time of day between airplane observations and those of kites upon which the normals are based.

Table 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 7 a.m. (E.S.T.) during August 1933*

[Wind from N=360°, E=90°, etc.]

Altitude (meters) m.s.l.	Albuquerque, N. Mex. (1,554 meters)		Atlanta, Ga. (309 meters)		Bismarck, N. Dak. (518 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (192 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	11	1.6	1	0.3	91	0.2	95	0.6	165	1.6	278	2.6	12	0.2	139	0.8	159	1.7	145	0.1	286	0.5	131	3.0
500			337	1.1			145	6.4	205	2.5			197	1.1	83	.3	203	6.6			263	2.4	136	5.6
1,000			306	1.7	197	3.4	146	6.4	257	3.4			274	.9	321	1.8	202	5.9	146	.6	233	2.1	136	6.0
1,500			290	2.7	215	2.2	137	5.0	271	4.3			281	1.6	290	3.4	192	3.6	259	1.0	219	2.2	136	5.3
2,000	132	1.3	275	2.8	281	2.9	125	4.6	282	5.2	267	3.1	295	3.3	288	4.2	216	1.3	276	3.2	225	2.4	132	4.4
2,500	218	1.7	275	2.6	297	5.4	107	4.0	272	6.6	250	3.6	293	3.9	269	4.8	327	1.6	253	3.1	230	2.8	129	4.1
3,000	253	2.1	278	2.6	293	6.7	98	3.9	274	6.4	260	4.1	283	4.7	268	6.0	17	1.8	254	3.9	221	3.1	129	4.1
4,000	275	2.9	280	2.3	302	9.5	77	3.0	276	8.0	274	5.0	293	3.4	259	6.6	23	2.6	250	5.5	234	3.5	121	3.6
5,000	271	2.4	283	1.1			68	3.0	286	3.1	292	7.5			268	6.5	336	3.6	255	9.0	252	3.3	123	2.6

Altitude (meters) m.s.l.	Los Angeles, Calif. (217 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (83 meters)		New Orleans, La. (2 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (402 meters)		Omaha, Nebr. (306 meters)		Phoenix, Ariz. (338 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D.C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	147	0.4	232	0.5	141	0.3	51	0.6	333	0.4	172	1.4	113	0.5	79	1.1	155	4.3	318	0.5	117	1.2	246	0.6
500	115	0.8	260	0.8	172	2.4	184	1.6	275	1.9	187	4.1	138	2.6	92	1.2			250	1.9	54	1.4	292	2.3
1,000	341	2.8	270	1.2	213	2.1	164	2.1	321	3.1	212	7.9	187	3.1	80	1.0			248	4.4	22	2.3	277	3.2
1,500	332	2.9	78	0.4	237	2.6	162	2.3	286	1.7	234	5.5	270	1.9	170	0.2	163	5.8	264	4.8	24	1.8	278	3.5
2,000	257	1.6	101	0.7	259	2.7	178	2.3	252	2.5	249	3.9	299	4.1	176	0.2	184	4.1	287	4.4	106	1.2	282	3.9
2,500	190	2.6	214	1.5	267	1.9	180	1.7	226	3.5	267	2.7	298	5.8	172	0.7	231	3.3	295	3.7	181	1.5	282	3.7
3,000	165	3.5	226	2.4	233	0.2	175	1.0	228	4.8	290	1.9	303	6.4	190	1.6	248	4.4	300	4.5	273	2.1	274	4.7
4,000	160	4.8	235	3.9	307	1.4	237	2.0			352	2.0	308	6.1	176	2.0	253	6.1	289	5.6	246	2.4	258	5.9
5,000			258	3.6	283	2.3	260	2.9			285	2.9	272	4.2	189	0.8	255	5.5	302	5.6	244	4.1	289	8.2

RIVERS AND FLOODS

By Richmond T. Zoch

[River and Flood Division, Montrose W. Hayes, in charge]

The tropical disturbance which passed over the Middle Atlantic States on August 23–24 caused rises in all the rivers of these States and the Delaware and Susquehanna passed the flood stage.

Reading, Pa., and Phillipsburg, N.J., had, during this flood, the highest actual gage readings of record although the water did not exceed the high-water marks which were reached before gages were established at these places. At Trenton, N.J., the water reached the highest stage since 1913. The Susquehanna did not reach a very high stage. The Delaware River caused considerable damage but with this exception, the rivers caused relatively little harm, as most of the damage was in the creeks and small tributary streams.

Very heavy downpours at and west of the Colorado-Kansas boundary in the headwaters of the Smoky Hill River on August 4–5 caused floods there. The property damage in Wichita and Scott Counties of Kansas was estimated at $57,000 which is a very large item for such a sparsely settled territory. The official in charge at Topeka, Kans., comments as follows on this flood:

> This flood spread across the comparatively level country with a wall of water reported 10 to 15 feet high and in places attained a depth of 25 feet. In its wake was a trail of ruined fields, wrecked farm buildings, and dead stock. Every bridge across Ladder (Beaver) Creek in Wichita County was washed out. Regular channels were ignored as head waters rolled over parched fields, pushing in the van heaps of weeds, hay, sticks, and debris with such force that a cloud of dust was raised as the flood progressed.

The very heavy rains around Shreveport, La., on July 23–26 (see article in the July issue of the Review) caused the Sabine River at Bon Wier, Tex., to rise from 10.4 on July 24 to 18.2 on July 25; it continued to rise until August 2, when it reached 23.0 feet, the highest stage of record. High stages were also reached at the other stations on the Sabine River.

A severe flood in Cherry Creek near Denver, Colo., will be discussed in a later issue of the Review.

Table of flood stages in August 1933

[All dates in August unless otherwise indicated]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
Lackawaxen: Hawley, Pa	9	24	24	10.0	24
Schuylkill: Reading, Pa	10	24	25	19.7	24
Delaware:					
Phillipsburg, N.J	22	25	25	25.0	25
Trenton, N.J	12	25	25	12.7	25
Susquehanna:					
Wilkes-Barre, Pa	18	24	25	20.1	25
Harrisburg, Pa	14	25	25	15.2	25
Santee:					
Rimini, S.C	12	17	31	14.9	20
Ferguson, S.C	12	20	25	12.2	23–24
MISSISSIPPI SYSTEM					
Missouri Basin					
Smoky Hill: Lindsborg, Kans	21	24	24	23.9	24
Grand: Gallatin, Mo	20	22	23	22.8	22
Arkansas Basin					
Fountain: Fountain, Colo	8	2	2	12.0	2
North Canadian:					
Woodward, Okla	5	20	20	5.3	20
		29	31	6.3	31
Canton, Okla	5	31	Sept. 1	6.3	Sept. 1
Canadian: Canadian, Tex	5	27	27	6.3	27
Arkansas: Arkansas City, Kans	15	29	29	15.0	29
WEST GULF OF MEXICO DRAINAGE					
Sabine:					
Logansport, La	25	July 24	2	34.6	July 25
Bon Wier, Tex	21	July 27	10	23.0	2
Orange, Tex	4	1	11	5.1	5–6
Trinity: Dallas, Tex	28	July 31	1	34.8	1
Pecos: Fort Sumner, N.Mex	5	4	4	5.5	4
Rio Grande: Mercedes, Tex	20	8	8	20.2	8

THE WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[By the Marine Division, W. F. McDonald, in charge]

NORTH ATLANTIC OCEAN

By W. F. McDonald

Atmospheric pressure.—The average pressure during August 1933, as of the two previous months, was below normal over the Atlantic between Cape Farewell and Iceland and also over the Antillean region, while the eastern Atlantic had a steady though small average excess in the monthly barometer values throughout the same period.

The highest pressures over the Atlantic during August were 30.40 to 30.50 inches, between the Azores and the English Channel on the first two days of the month, and again on the 20th between the Azores and Newfoundland. The lowest reported pressure was 28.54 inches, observed on the 23d off Cape Hatteras by the American tankship *R. J. Hanna* while in a tropical hurricane. Two days later the Polish steamship *Pulaski* recorded 28.78 inches near the center of a different depression (of extra-tropical origin) on the fifty-fifth parallel about midway between Belle Isle and Ireland.

The Atlantic HIGH was well developed and stable until August 23d, but it was greatly weakened thereafter, especially between the 24th and 28th, when the highest barometric readings were only 30.00 to 30.10 inches.

Table 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, August 1933*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.62		29.92	19	29.25	16
Reykjavik, Iceland	29.63	−0.18	30.11	11	29.08	17
Lerwick, Shetland Islands	29.80	.00	30.30	12	29.25	18
Valencia, Ireland	30.05	+.13	30.44	3	29.57	15
Lisbon, Portugal	30.05	+.03	30.20	14	29.90	24
Madeira	30.05	+.02	30.18	14	29.87	15
Horta, Azores	30.21	+.01	30.42	14	29.93	27
Belle Isle, Newfoundland	29.86	−.03	30.16	21	29.42	3
Halifax, Nova Scotia	30.03	+.02	30.38	7	29.76	26
Nantucket	30.00	+.01	30.40	7	29.61	25
Hatteras	29.96	−.04	30.24	7	28.67	23
Bermuda	30.07	−.07	30.22	1, 2	29.66	21
Turks Island	29.97	−.07	30.08	3	29.80	22
Key West	29.94	−.04	30.07	14	29.71	22
New Orleans	29.96	−.02	30.12	14	29.74	23
Cape Gracias, Nicaragua	29.86	−.02	29.92	11, 12	29.76	23, 25

Note.—All data based on a.m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—The major storms of the month were of tropical origin, as discussed briefly under the succeeding topic heading and more fully in another place in this issue.

During all of the month, the higher latitudes of the Atlantic were almost continually under the influence of a succession of slow moving barometric depressions, central generally between Iceland and Labrador. These reached their deepest development and greatest extent on the 25th and 26th, when scattered gales occurred along the northern steamship lanes from the 25th to the 60th meridians, and the Polish steamship *Pulaski* on the 25th experienced winds reaching force 11 near the center (barometer 28.78 inches) of the main depression in mid-Atlantic, as noted above.

Cold front disturbances occurred at times on the southern side of the high-latitude depressions, especially during the first half of the month. The most vigorous of these, on the 1st, causing localized gales of force 10 above latitude 40° about half way between Newfoundland and the Azores.

Apart from these few occasions the Atlantic north of the 40th parallel was almost entirely free from gales during August.

Gales connected with tropical disturbances were experienced on some part of the waters south of latitude 40° and west of the 50th meridian on over half the days of the month, that is, from the 1st to 4th, 15th to 23d, and the last 3 days. These gales, while not in all cases clearly identified with active centers of low barometer, for the most part attended definite tropical disturbances.

Tropical disturbances.—The month began with a hurricane in progress in the Gulf of Mexico approaching the end of a long track that started a week earlier, beyond the island of Antigua. No ship in the Gulf seems actually to have encountered a well-defined center in this storm as it passed westward to the mouth of the Rio Grande, and the highest wind reported by marine observers was only a strong gale, in the eastern part of the Gulf, on the 1st. The storm center displayed full hurricane intensity, however, when it crossed the coast near Brownsville, Tex., on August 5.

The next tropical disturbance of major importance to shipping was of hurricane intensity on the 22d and 23d, as it crossed the main Gulf Stream sailing routes off Cape Hatteras, where many ships were involved. This hurricane is described in detail elsewhere in this issue. It receives comment here only with special reference to its effects on maritime commerce.

Throughout the long course of this storm, beginning in the little traveled ocean area, probably far east of the intersection of the 15th parallel and the 50th meridian, its progress was identified from day to day after the 16th in storm conditions reported by ships, and reproduced in the accompanying table of gales.

The highest wind experienced by any reporting ship along the storm track before the hurricane neared the coast, was of force 11, reported on the 18th by the French steamship *Cuba*, in the right-hand semicircle of the storm near latitude 22° N., longitude 53° W.

In the vicinity of Cape Hatteras and off the entrance to Chesapeake Bay, full hurricane intensity was experienced by a number of vessels, five of which (all American) the *Cities Service Kansas*, *Nebraskan*, *Trimountain*, *Shenandoah*, and *Bohemian Club*, have forwarded reports of winds reaching force 12 (hurricane). (See table.)

The synoptic weather charts for Greenwich mean noon of August 22 and 24 are reproduced herewith as charts X and XI, to show this storm as the center approached the coast, and again as it was rapidly diminishing in intensity after having passed inland over the Atlantic coastal region.

Notwithstanding the full hurricane intensity attained by this disturbance, and the considerable number of ships involved in its passage over the coastwise shipping routes, there was no major loss at sea, although small craft in coastal waters suffered disastrously.

At the end of the month another hurricane was in progress off the north coast of Cuba, having moved in the preceding 3 days steadily westward from the open Atlantic northeast of the Virgin Islands. The first ship to report hurricane winds in this storm was the Dutch steamer *Astrea*, which was not far from the center at 3:30 p.m. of August 30, about 10 miles north of Grand Turk Light. The barometer fell to 29.27 inches, hurricane winds were experienced for about 2 hours, and the wind direction shifted from west through southwest to south, without diminution in force about the time of lowest barometer. No other ship reported higher than whole-gale winds in connection with this disturbance in August, although hurricane intensity was again revealed as the center passed westward near Habana in the first days of September. Further notes regarding the marine phases of this storm in September will be carried in next issue.

Fog.—Fog had a normal distribution over the North Atlantic during August, being strongly banded between Cape Cod, the Grand Banks, and the entrance to the English Channel. It was reported at greatest frequency, on two thirds of the days of the month, southward from the Gulf of Maine, and on 10 to 14 days thence eastward to the Grand Banks. Elsewhere along the steamer routes fog occurred generally on only 3 to 7 days in the month.

Trans-Atlantic aviation.—The French aviators, P. Codos and M. Rossi, left New York early on August 5, with the object of crossing the Atlantic and continuing eastward in an effort to exceed the existing nonstop record. They landed 60½ hours later near Beirut, Syria, and so established a new record for distance in a single flight.

On August 8 General Italo Balbo and his squadron of 24 Italian army planes left Newfoundland for the Azores, arriving the same day. The flight from the Azores to Lisbon was accomplished on August 9.

The synoptic maps for August 6 and 8, to show conditions over the Atlantic at the time of these crossings, are given as charts VIII and IX.

OCEAN GALES AND STORMS, AUGUST 1933

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
North Atlantic Ocean			° ′	° ′				Inches					
S. M. Spalding, Am.S.S.	Baytown	Baltimore	25 00 N	86 05 W	Aug. 1	6p., Aug. 1.	Aug. 2	29.84	WNW	SE	SW	—, 8	NW-SW-SE.
Jamaica Pioneer, Br.S.S.	Jamaica	London	42 48 N	41 48 W	do	3p., 1	Aug. 1	29.76	SSW	SW, 10	W	SW, 10	SW-W.
Duquesne, Am.S.S.	Galveston	Bremen	46 02 N	35 02 W	do	8p., 1	do	29.45	SW	SE, 9	NW	N, 10	SW-SE-N.
Walter Jennings, Am.S.S.	Aruba	New York	14 51 N	69 12 W	Aug. 2	4a., 2	Aug. 2	29.90	E	E, 6	ENE	—, 8	
Blythmoor, Br.S.S.	Durban	St. John	13 26 N	27 14 W	Aug. 13	8a., 14	Aug. 14	29.62	NW	NNE, 7	S	NNE, 7	N-NNE-S.
Ancon, Am.S.S.	Cristobal	New York	17 00 N	75 30 W	Aug. 15	5 p., 15	Aug. 15	29.74	SE	SE, 6	SE	—, 7	SE-W.
Eliane L. D., Fr.S.S.	Gibraltar	Port Churchill.	53 45 N	32 08 W	Aug. 16	Noon, 16	Aug. 17	29.47	SW	W, 7	WNW	W, 8	SSW-W-WNW.
West Selene, Am.S.S.	Savannah	Rio de Janeiro.	14 30 N	48 30 W	do	10 p., 16	do	29.61	NNW	NW, 8	SW	W, 9	NNW-NW-W.
Cavina, Br.S.S.	Avonmouth	Barbados	18 46 N	55 12 W	Aug. 17	6 p., 17	Aug. 18	29.78	ENE	NE, —	W	N, 8	NE-N-NW.
Cuba, Fr.S.S.	Bordeaux	Martinique	22 22 N	52 40 W	do	Noon, 18	do	29.65	ESE	ESE, 10	SSW	SE, 11	ESE-SE-SSE.
Schuylkill, Br.M.S.	Liverpool	Aruba	26 20 N	53 43 W	Aug. 18	4a., 19	Aug. 19	29.92	ESE	ESE, 8	S	ESE, 8	ESE-SE-S.
Dorothy, Am.S.S.	New York	San Juan	32 44 N	71 49 W	Aug. 21	Noon, 21	Aug. 22	29.43	E		S	NW, 9	8 points.
E. M. Clark, Am.S.S.	Baltimore	Las Piedras	32 21 N	74 35 W	Aug. 22	4 p., 22	do	29.28	NE	WNW, 10	SW	WNW, 10	N-NW-W.
J. A. Moffett, Jr., Am.M.S.	Corpus Christi.	Boston	33 40 N	75 10 W	do	11 p., 22	Aug. 23	28.91	NE	N, 10	SW	N, 10	N-WNW
Gulfwing, Am.M.S.	Philadelphia	Las Piedras	36 03 N	73 14 W	do	Mdt., 22	do	29.19	NE	E, 11	S	ESE, 11	ENE-E-ESE
Cities Service Kansas, Am.S.S.	Port Arthur	Boston	33 34 N	76 32 W	do	1 a,, 23	do	29.14	N	N, 11	SW	N, 12	N-WNW-SW
S. M. Spalding, Am.S.S.	Baytown	New York	34 40 N	75 15 W	do	2 a., 23	Aug. 24	28.84	NE	NW, 10	SSW	—, 10	NNE-N-NW
Nebraskan, Am.S.S.	Panama Canal.	do	35 09 N	74 46 W	Aug. 21	2 a., 23	Aug. 23	28.61	N	SSE, 11	S	SSE, 12	NE-E-S
R. J. Hanna, Am.S.S.	Houston	Marcus Hook	35 30 N	75 00 W	Aug. 22	3 a., 23	do	28.54	NE	E, 8	S	NE, 11	NE-E-S
Trimountain, Am.S.S.	Cuba	Philadelphia	[1] 36 00 N	73 20 W	do	3 a., 23	Aug. 24	28.57	NE	Var. 12	S	Var. 12	ENE-SSW-S
Shenandoah, Am.S.S.	Port Arthur	New York	35 20 N	74 30 W	do	4 a., 23	do	28.63	NE	SSE, 12	S	SSE, 12	NE-SSE
Bohemian Club, Am.S.S.	do	Philadelphia	35 43 N	75 05 W	Aug. 21	4 a., 23	Aug. 23	28.88	NNE	E, 12	S	E, 12	NE-E-S
San Blas, Pan.S.S.	Philadelphia	Belize	37 00 N	75 00 W	Aug. 22	8 a., 23	do	28.86	NE	ESE, 10	SSW	ESE, 10	E-SE-S
Pulaski, Pol.S.S.	Gdynia	New York	[1] 54 43 N	34 34 W	Aug. 24	4 a., 25	Aug. 26	28.78	SSW	W, 7	NW	NNW, 11	W-NW
Blythmoor, Br.S.S.	Durban	St. John	40 15 N	61 50 W	Aug. 25	5 p., 25	Aug. 25	29.75	WNW	SW, 8	SW	WSW, 8	WSW-SW
Gonzenheim, Ger.S.S.	Bristol	Botwood	53 03 N	24 57 W	do	7 a., 26		29.22	S	SW, 6		S, 8	S-SW
Wyoming, Fr.S.S.	Havre	Puerto Columbia.	19 40 N	61 10 W	Aug. 30	5 p., 31	Sept. 1	29.77	ENE	SE, 7	SSW	SE, 7	
Mariana, Am.S.S.	Arroyo	New Orleans	21 12 N	75 21 W	Aug. 31	7 a., 31	Aug. 31	29.66	WNW	WSW, 7	S	SW, 8	W-SW.
Astrea, Du.S.S.	New York	Maracaibo	21 37 N	71 14 W	Aug. 30	3 p., 30	Aug. 30	29.27	NNW	SW, 12	S	SW, 12	W-S.
NORTH PACIFIC OCEAN													
Illinois, Am.S.S.	Otaru	San Francisco.	34 06 N	126 37 E	Aug. 3	5 p., 3	Aug. 3	28.79	NE	N, 10	NW	NE, 12	NE-N.
Grays Harbor, Am.S.S.	Tacoma	Yokohama	52 39 N	158 33 W	Aug. 6	11 p., 8	Aug. 10	29.37	S	WNW, 1	WNW	NW, 9	W-NW.
Nitro, U.S.S.	San Diego	Balboa	13 41 N	95 01 W	Aug. 12	4 a., 13	Aug. 13	29.79	WNW	S, 7	S	SW, 8	
Chiloil, Am.S.S.	San Francisco.	do	14 40 N	96 00 W	Aug. 13	8 p., 13	Aug. 14	[2] 29.48	NE	NNW, 7	SW	SW, 10	NW-W-SW.
Pres. Wilson, Am.S.S.	Los Angeles	do	[1] 14 58 N	97 13 W	Aug. 16	7 p., 16	Aug. 16	29.78	SE	SE, 9	SE	SE, 9	None.
Pennsylvanian, Am.S.S.	Balboa	Los Angeles	20 17 N	106 48 W	Aug. 18	6 p., 18	Aug. 19	29.67	SE	SE, 8	E	SE, 8	SE-E.
Golden Dragon, Am.S.S.	Astoria	Yokohama	50 35 N	180 00	Aug. 21	4 p., 21	Aug. 23	28.86	SSE	SSW, 5	NW	WNW, 10	S-SSW-W.
Heian Maru, Jap.M.S.	Yokohama	Vancouver	48 36 N	176 54 E	do	Noon, 22	Aug. 22	29.29	WNW	WNW, 8	WNW	WNW, 8	None.
Pres. Cleveland, Am.S.S.	do	Seattle	50 02 N	164 54 W	Aug. 24	8 p., 24	Aug. 25	29.78	N	N, 9	SSW	N, 9	N-ESE.
Fernbrook, Nor.M.S.	Los Angeles	Yokohama	37 45 N	150 35 E	Aug. 27	11 a., 27	Aug. 27	29.68	SSE	SW, 9	WSW	SW, 9	SSE-S-WSW.

[1] Position approximate.

[2] Uncorrected.

NORTH PACIFIC OCEAN, AUGUST 1933

By W. F. McDonald

Atmospheric pressure.—The weather of the Pacific Ocean during August 1933 was in the main dominated by settled high pressure conditions. Average barometric readings were below normal over Alaska (notably at Point Barrow) and along the Mexican coast, but a slight excess in average pressure prevailed over most of the Pacific. (See table 1.)

Around the middle of the month the Pacific anticyclone was weak and at times badly disrupted by southward extensions from vigorous low pressure areas in the Aleutian region where the lowest barometer reached 28.86 inches on the 21st. During the last 10 days of the month, however, high pressures were well established and at times spread far northward to cover the Gulf of Alaska and Bering Sea.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, August 1933, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow	29.72	−0.17	30.06	15, 31	29.36	20
Dutch Harbor	29.82	−.04	30.26	31	29.20	22
St. Paul	29.91	+.13	30.32	31	29.08	22
Kodiak	29.82	−.04	30.30	24	29.38	15
Juneau	30.00	−.02	30.39	23	29.71	18
Tatoosh Island	30.02	+.02	30.20	21	29.80	26
San Francisco	29.90	−.02	30.08	3	29.67	13
Mazatlan	29.81	−.10	29.96	1	29.72	13
Honolulu	30.07	+.06	30.15	7	29.96	23
Midway Island	30.11	+.03	30.22	5	29.94	25
Guam	29.83	+.01	29.90	3	29.74	14
Manila	29.79	−.01	29.88	24	29.56	1
Naha	29.75	+.06	29.94	24	28.28	1
Chichishima	29.83	+.07	30.04	3	29.58	6
Nemuro	29.89		30.10	2, 16	29.70	13

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Cyclones and gales.—The month was in general very quiet and entirely free from cyclonic action over most of the vast expanse of tropical and middle latitudes in the Pacific. The Aleutian LOW was well developed during brief periods, notably between the 8th and 10th, the 13th to 17th, and 21st to 24th, but extratropical depressions for the most part followed tracks that led northeastward into Alaska rather than eastward along the main ship routes.

Localized gales were reported south of the Aleutians, between August 21 and 24, the strongest of force 10, as reported in detail in the accompanying table of gales.

A gale of force 9 was reported by one ship on the 9th in the western part of the Gulf of Alaska, and another on the 27th, about 400 miles east of Yokohama. No other gale reports have been received from the main trans-Pacific sailing routes.

Typhoons.—The month began with a full-fledged typhoon in progress, moving northward near the island of Naha. This storm was described in some detail in the July REVIEW, as originating near Guam on July 26, and breaking up over the Japan Sea after August 4.

The winds near the center continued of full hurricane intensity as the storm passed Naha on August 1, with the barometer down to 28.28 inches at the observing station on that island, and a 70-mile wind from the south. On August 3, the American steamship *Illinois* encountered the same storm near the south entrance to the Strait of Korea, and experienced a northeast hurricane with winds shifting through north to west, and a minimum barometer reading of 28.79 inches. The typhoon passed on inland over Korea, where much damage resulted.

At the close of the month another deep cyclonic depression, apparently of tropical origin, was passing northward between Naha and Formosa, but no details from ships' reports or other sources are available at this writing to indicate the full intensity or further history of this typhoon. A more complete account will appear later.

Mexican west-coast cyclones.—A small disturbance of considerable intensity appeared off the south coast of the Isthmus of Tehuantepec on August 12, moved slowly northwestward to the vicinity of Cape Corrientes by the 18th and appears to have dissipated in the Gulf of California on the 19th or 20th. Several vessels experienced gales at points along the track of this disturbance.

The American tanker *Chiloil* reported a barometer reading of 29.48 inches (uncorrected) near latitude 15° N., longitude 96° W., at 8 p.m. of the 13th, attended by a whole gale, with winds shifting from northwest to southwest as the disturbance passed.

Early on the morning of the 14th the British steamship *Nebraska*, about 50 miles to westward from the position given by the *Chiloil*, encountered a hurricane wind lasting for 2 hours, with the lowest barometer (uncorrected), 29.60 inches. No other ship reported winds in excess of a strong gale in connection with the further progress of this disturbance.

An interesting note prepared by the Canal Zone meteorologist, Mr. L. T. Chapel (by whose courtesy the report from the *Nebraska* was obtained and forwarded) is appended because of the light it throws upon conditions that doubtless contributed to the origin of this Mexican west-coast disturbance.

Fog.—Fog was most prevalent on the American coast from Puget Sound to Cape San Lucas, and occurred at greatest frequency on about half the days of the month along the California coast. On the northern steamship routes fog was reported on from 2 to 7 days, and most frequently between 155° and 180° east longitude.

NOTE ON THE PROBABLE INTRUSION OF SOUTHERN HEMISPHERE AIR TO THE REGION OF PANAMA

By L. T. CHAPEL

[Hydrographic Office, the Panama Canal]

The report from the British steamship *Nebraska* on August 13–14, 1933, indicates a mature storm near latitude 14°30′ N., longitude 97° W. This storm should have formed within five or six hundred miles to the westward of Panama. Usually when a cyclonic storm forms this close to Panama in the Pacific, there are more or less marked effects on Panama weather, although not in the same degree as in the case of Caribbean storms. The effects noted in Panama seem capable of interpretation only on the theory that these storms in the Pacific originate between the northeast trades and winds from the southeast trades which, after crossing the Equator, have become south to southwest.

In this particular storm the influence on local winds was not sufficient to be positively identified, the only marked effects being noted in sea swells and temperature and humidity of the air.

The naval radio station at Cape Mala reports (at 7 a.m.) the wind in Beaufort scale and the state of the sea. The winds reported were very light and variable during the week preceding the discovery of this storm. The reports on state of the sea at Cape Mala and mean temperature, 8 a.m. and 8 p.m. dew point at Cristobal follow:

	Cape Mala, sea	Cristobal, mean temperature	8 a.m. dew point	8 p.m. dew point
Aug. 7	Heavy swell	82	76	76
Aug. 8	Moderate sea	82	76	76
Aug. 9	Rough sea	77	75	*71*
Aug. 10	Heavy surf	80	*71*	74
Aug. 11	Smooth sea	82	74	77
Aug. 12	Moderate sea	81	76	74
Aug. 13	Smooth sea	80	73	75

At this time of the year, the sea at Cape Mala is usually smooth, and Pacific air is always dryer and cooler than Caribbean air. The above data would seem to indicate that the maximum force of the intrusion northward occurred about August 9 and 10—about the right time for the initial development of this storm. Incidentally, mean sea level in Panama Bay rose about a half foot from August 5 to August 9 and then fell to its original level by August 17. This is not unusual in itself but merely accords with the other data.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, August 1933

[For description of tables and charts, see Review, January, p. 37]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	80.0	+0.4	2 stations	100	[1] 1	Talladega	55	28	3.99	−0.51	Troy No. 1	10.63	Tuscumbia	0.61
Arizona	81.5	+1.5	do	124	[1] 10	Bright Angel Ranger Station.	33	4	1.56	−.72	Williams	6.53	Quartzsite	.00
Arkansas	79.1	−.6	3 stations	101	10	Dutton	49	16	4.42	+.70	Freeman Springs	7.88	Warren	1.01
California	73.1	+.8	Greenland Ranch	127	12	Tule Lake	25	30	.07	−.02	Shield's ranch	2.15	139 stations	.00
Colorado	65.8	+.6	Palisade	105	[1] 13	Pearl	20	23	2.23	+.26	Yuma	7.58	Bloom	T
Florida	81.7	+.3	Blountstown	101	30	3 stations	65	[1] 7	6.72	−.34	Fort Lauderdale	14.88	Pensacola	1.87
Georgia	80.0	+.6	Millen	103	[1] 9	2 stations	52	[1] 5	4.19	−.97	Savannah No. 2	8.98	Hawkinsville	.86
Idaho	65.9	−.5	Weiser	109	14	Atlanta	20	[1] 4	.38	−.29	Cottonwood	2.24	4 stations	.00
Illinois	73.5	−.4	Mascautah	102	12	3 stations	44	19	2.62	−.73	Chester	8.56	Edwardsville	.65
Indiana	72.8	−.4	2 stations	100	2	Wheatfield	42	19	2.79	−.57	Muncie	5.30	Whitestown	.86
Iowa	70.5	−1.4	Thurman	101	6	2 stations	41	30	3.01	−.56	Bedford	10.98	Oelwein	.45
Kansas	76.7	−.6	3 stations	109	[1] 6	Valley Falls	49	30	5.21	+2.00	St. Francis	11.15	Sublette	1.61
Kentucky	74.7	−.9	2 stations	99	[1] 2	2 stations	51	15	3.30	−.39	Burnside	7.95	Pikeville	.87
Louisiana	81.9	+.2	do	99	[1] 3	Cinclare	62	25	4.17	−.89	Calhoun	9.78	De Ridder	1.14
Maryland-Delaware	74.0	+.8	Elkton, Md	100	1	2 stations	40	30	10.29	+5.97	Bridgeville, Del	15.59	Frostburg, Md	3.61
Michigan	66.7	+.1	Owasso	98	1	Wolverine	28	15	1.74	−.91	Gull Lake	3.59	Harrisville	.16
Minnesota	67.4	+.2	Beardsley	104	6	Big Falls	29	29	1.66	−1.51	Worthington	5.16	Collegeville	.16
Mississippi	80.8	+.3	Holly Springs	101	19	State College	56	6	3.65	−.67	Merrill	8.03	Enterprise	1.10
Missouri	75.4	−.7	St. Charles	103	12	2 stations	48	[1] 14	3.91	−.03	Gallatin	10.62	Valley Park	.36
Montana	65.5	+.8	6 stations	103	5	do	25	26	2.52	+1.35	Highwood	7.08	Superior	.36
Nebraska	71.5	−1.4	Beatrice	106	6	Scottsbluff	36	25	3.90	+1.08	Benkleman	10.93	Taylor	1.08
Nevada	72.2	+2.0	Logandale	120	12	Sheldon	22	21	.19	−.33	Minden	.99	4 stations	.00
New England	67.5	+.6	Turners's Falls, Mass	102	1	Van Buren, Maine	33	6	5.22	+1.30	Chesterfield, Mass	11.51	Houlton, Maine	1.84
New Jersey	72.7	+.9	3 stations	101	1	Charlotteburg	45	15	10.53	+5.78	Pleasantville	15.15	Sandy Hook	6.45
New Mexico	71.1	+.6	2 stations	106	[1] 1	Selsor Ranch	29	29	3.06	+.59	Ione	9.50	Shiprock	.42
New York	68.1	+.7	do	104	1	Indian Lake	31	10	6.42	+2.59	Rifton	12.42	Buffalo	2.41
North Carolina	75.7	−.1	3 stations	100	[1] 1	Mount Mitchell	43	6	5.75	+.23	Wenona	10.35	Rocky Mount	2.64
North Dakota	68.5	+2.3	Carrington	104	20	Edmore	31	28	.73	−1.31	Hankinson	2.37	Carrington	.10
Ohio	72.1	+.6	2 stations	100	1	Millport	43	29	3.43	+.11	Ironton	9.34	Hiram	.90
Oklahoma	79.7	−1.3	Jefferson	112	9	Beaver	51	30	5.28	+2.26	Seminole	12.20	Durant	1.61
Oregon	66.3	+1.0	Wolf Creek	110	15	Seneca	18	30	.41	−.02	Headworks	4.38	5 stations	.00
Pennsylvania	70.8	+.8	Phoenixville	104	1	Coudersport	38	30	7.61	+3.44	York	17.70	Grove City	1.22
South Carolina	79.3	+.5	Blackville	105	10	2 stations	58	[1] 7	4.71	−.99	Santuck	10.14	Florence no. 2	1.02
South Dakota	70.3	−.1	Strool	106	5	Winner	37	21	2.35	+.02	Hot Springs	6.89	Redfield	.47
Tennessee	76.1	−.3	2 stations	99	27	Rogersville	51	15	4.62	+.59	Copperhill	9.28	Lynville	1.38
Texas	82.5	−.3	Memphis	110	9	Dalhart	55	21	3.06	+.62	Hebbronville	8.58	Rocksprings	.11
Utah	69.5	−.1	St. George	111	12	Soldiers Summit	23	22	.52	−.53	Panguitch	1.90	Orris Ranch	T
Virginia	74.4	+.4	2 stations	99	[1] 1	4 stations	49	[1] 6	5.78	+1.46	Williamsburg	16.64	Wytheville	1.29
Washington	66.9	+2.8	Wawawai	109	16	Bumping Lake	29	31	.86	+.09	Carbon River	3.87	White Swan	.00
West Virginia	71.5	−.1	Martinsburg	102	1	Bayard	38	30	5.38	+1.39	Dam 19 O.R.	9.84	Sharples	1.28
Wisconsin	67.0	−.4	Friendship	99	23	Long Lake	29	29	1.58	−1.60	Darlington	5.97	Ladysmith	.00
Wyoming	62.8	−1.1	Devil's Tower	103	5	South Pass City	20	22	1.78	+.66	Pine Bluffs	4.91	Kemmerer	.15
Alaska (July)	55.6	−.9	Allakaket	90	28	Barrow	22	17	1.77	−.90	Ketchikan	10.69	White Mountain	T
Hawaii	73.2	−1.6	4 stations	90	[1] 1	Kanalohuluhulu	45	29	2.69	−4.06	Keauhou no. 2	12.57	13 stations	.00
Puerto Rico	78.9	−.2	Mayaquez	96	28	Guineo Reservoir	49	25	6.41	−.82	Coloso	15.00	San Francisco	1.74

[1] Other dates also

TABLE 1.—*Climatological data for Weather Bureau stations, August 1933*

[Compiled by Annie E. Small]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							68.4	+1.0										82	4.28	+0.7										6.3		
Eastport	76	67	85	29.94	30.02	+0.06	61.6	+0.9	85	2	69	50	7	54	28	58	57	90	4.45	+1.4	12	5,858	sw.	29	e.	26	6	7	18	7.0	0.0	0.0
Greenville, Maine	1,070	6		28.87	30.02		63.0		82	17	73	40	12	53	34				3.34		11	3,003	se.	16		2	10	9	12		.0	.0
Portland, Maine	103	82	117	29.89	30.01	+.03	67.9	+1.5	90	2	75	57	7	61	21	63	61	82	2.85	-.3	15	5,618	n.	24	sw.	13	9	8	14	6.0	.0	.0
Concord	289	60		29.70	30.00	+.02	67.4	+.6	97	1	78	46	10	56	35				6.01		13		n.								.0	.0
Burlington	403	11	48	29.56	29.99	+.02	66.8	-1.1	91	1	77	47	6	57	29				4.47	+1.1	12	6,165	s.	27	s.	18	9	7	15	6.1	.0	.0
Northfield	876	12	60		30.02	+.04	63.8	+.4	95	1	76	38	10	51	37			80	3.98	+.4	9	4,980	s.	21	s.	24	4	12	15	6.5	.0	.0
Boston	125	106	165	29.88	30.01	+.02	71.8	+1.9	95	2	80	55	4	64	25	64	61	74	3.41	-.2	15	5,905	sw.	24	s.	24	7	14	10	6.2	.0	.0
Nantucket	12	14	90	29.99	30.00	+.01	69.4	+1.6	84	28	75	57	7	64	17	66	65	89	3.99	+.6	9	9,780	sw.	34	n.	4	11	5	15	5.9	.0	.0
Block Island	26	11	46	29.98	30.00	+.01	69.6	+1.1	84	27	75	60	11	65	17	67	66	90	4.68	+1.0	16	9,551	s.	32	n.	4	6	11	14	6.2	.0	.0
Providence	160	215	251	29.84	30.01	+.02	71.3	+.3	95	2	79	57	10	64	25	65	62	75	2.68	-.8	13	7,345	nw.	32	s.	24	10	7	14	5.8	.0	.0
Hartford	159	70	104	29.84	30.00	+.01	71.2	+2.3	97	1	80	54	10	63	29				4.91	+.6	16						10	5	16	6.3	.0	.0
New Haven	106	74	153	29.89	30.00	+.01	71.8	+1.5	96	2	79	57	7	64	23	66	63	76	7.39	+3.1	17	6,553	n.	31	e.	23	5	8	18	6.8	.0	.0
Middle Atlantic States							74.0	+0.6										77	8.75	+4.4										6.0		
Albany	97	107	115	29.90	30.00	+.02	71.0	+.2	101	1	80	51	30	62	28	64	60	74	5.95	+2.2	16	5,480	s.	24	s.	13	9	9	13	5.7	.0	.0
Binghamton	871	60	68	29.09	30.00	+.01	68.2	+.2	94	1	78	48	30	58	33				7.28	+3.7	12	3,896	ne.	21	e.	23	9	5	17	6.8	.0	.0
New York	314	414	454	29.66	29.98	-.02	73.8	+.7	95	1	80	58	11	67	21	67	64	75	9.21	+4.9	16	8,885	n.	51	se.	24	7	9	15	6.3	.0	.0
Bellefonte	1,050	5	42	28.90	29.99		68.4		91	1	79	44	30	58	33	63	60	80	7.14		13		sw.	34	ne.	23	6	13	12	6.3	.0	.0
Harrisburg	374	94	104	29.58	29.97	-.04	73.2	+.6	97	1	81	56	30	65	24	66	62	73	10.67	+6.6	14	5,278	ne.	34	ne.	23	10	11	10	5.6	.0	.0
Philadelphia	114	123	367	29.87	29.99	-.01	76.0	+1.2	97	1	83	60	11	69	21	68	64	72	9.84	+5.2	14	9,009	ne.	42	se.	23	10	5	16	6.3	.0	.0
Reading	325	283	304	29.64	29.98		72.8	+.4	97	1	81	56	30	65	25	66	63	74	7.53	+3.3	13	7,721	se.	52	e.	23	10	10	11	5.9	.0	.0
Scranton	805	72	104	29.15	30.00	.00	70.0	+.2	95	1	80	49	30	60	32	62	59	72	8.06	+4.4	15	4,524	n.	21	nw.	1	8	15	8	5.5	.0	.0
Atlantic City	52	37	172	29.92	29.97	-.03	74.5	+2.0	92	26	80	61	12	69	20	70	68	82	14.50	+10.0	14	11,763	s.	65	e.	23	8	8	15	6.4	.0	.0
Sandy Hook	22	10	55	29.96	29.98		74.1		97	2	80	60	11	69	22	68	66	81	6.45	+1.5	17	9,652	ne.	39	s.	24	8	11	12	5.8	.0	.0
Trenton	190	159	183	29.78	29.98		73.5	+.5	98	1	82	56	11	65	25	67	64	77	10.09	+5.3	16	6,525	n.	34	se.	23	6	12	13	6.2	.0	.0
Baltimore	123	100	215	29.84	29.97	-.04	77.0	+1.5	99	1	85	62	11	69	21	69	65	70	13.83	+9.5	13	7,718	sw.	50	ne.	23	10	8	13	6.0	.0	.0
Washington	112	62	85	29.85	29.96	-.05	76.0	+1.0	98	1	84	60	5	68	25	69	66	76	9.91	+5.9	14	4,642	s.	35	ne.	23	12	9	10	5.3	.0	.0
Cape Henry	18	8	54	29.93	29.95		77.8	+.9	97	2	84	68	6	72	23	72	70	82	8.68	+3.8	13	9,323	sw.	66	ne.	23	8	15	8	5.3	.0	.0
Lynchburg	686	153	188	29.26	29.99	-.03	75.6	.0	97	1	86	54	30	65	34				3.50	-.3	15		s.								.0	.0
Norfolk	91	170	205	29.88	29.97	-.03	78.4	+1.0	94	13	86	67	29	71	21	72	70	83	13.13	+7.9	13	8,758	ne.	57	ne.	23	5	11	15	6.6	.0	.0
Richmond	144	11	52	29.83	29.98	-.03	76.6	+.1	95	1	85	60	30	68	25	70	68	83	8.84	+4.4	17	5,790	ne.	39	ne.	23	9	9	13	6.1	.0	.0
Wytheville	2,304	49	55	27.68	29.98	-.03	69.8	-.7	89	2	79	50	6	60	32	64	61	81	1.29	-2.9	15	4,074	w.	21	w.	2	6	15	10	5.9	.0	.0
South Atlantic States							79.2	+0.8										82	5.81	+0.1										6.0		
Asheville	2,253	89	104	27.73	30.01	-.01	72.2	+1.7	90	2	82	54	7	62	31	65	63	85	4.34	+.2	16	4,335	nw.	23	se.	29	2	16	13	6.5	.0	.0
Charlotte	779	244	267	29.18	30.00	-.02	76.7	-.4	93	27	85	62	30	69	22	69	66	78	5.27	+.2	13	7,334	ne.	29	sw.	11	5	12	14	6.3	.0	.0
Greensboro	886	6	56	29.07	30.00		75.4		94	2	85	57	7	66	28	69	68	85	8.99		14	5,154	ne.	26	nw.	1	6	9	16	6.4	.0	.0
Hatteras	11	5	50	29.95	29.96	-.04	79.8	+1.8	89	11	85	72	30	75	14	75	74	82	9.41	+3.7	17	9,232	sw.	62	ne.	22	9	13	9	5.4	.0	.0
Raleigh	376	103	146	29.59	29.97	-.04	77.2	+.2	94	1	86	62	6	69	23	70	68	81	6.02	+.6	18	6,150	sw.	32	w.	23	4	12	15	6.8	.0	.0
Wilmington	72	73	106	29.91	29.98	-.02	79.2	+1.6	94	11	86	67	31	72	23	74	73	87	6.45	+.1	19	6,377	sw.	30	nw.	11	7	12	12	6.2	.0	.0
Charleston	48	11	92	29.93	29.98	-.03	81.4	.0	95	11	88	71	23	75	21	75	74	83	8.69	+2.2	18	7,346	sw.	30	ne.	12	11	8	12	5.5	.0	.0
Columbia, S.C	351	41	57	29.61	29.99	-.02	80.3	+.7	99	10	89	66	30	71	25	72	70	79	3.85	-1.6	12	4,956	ne.	21	s.	18	8	14	9	5.6	.0	.0
Augusta	182	62	77	29.78	29.97	-.04	81.5	+1.1	99	10	91	68	23	72	27	72	70	74	3.89	-1.1	9	4,284	s.	21	w.	28	8	15	8	5.2	.0	.0
Savannah	65	73	152	29.93	30.00	-.01	82.2	+1.5	97	27	91	70	7	74	26	74	73	83	5.49	-1.8	14	6,648	sw.	27	w.	13	12	6	13	5.6	.0	.0
Jacksonville	43	209	245	29.94	29.99	-.02	82.0	+.3	95	28	89	69	21	74	18	74	73	81	4.68	-1.1	9	6,577	sw.	37	sw.	28	5	19	7	6.0	.0	.0
Florida Peninsula							82.9	+0.8										79	8.06	+1.8										6.1		
Key West	22	10	64	29.92	29.94	-.04	83.6	+.1	92	23	89	72	16	79	16	77	75	77	4.90	+.4	13	7,009	e.	25	se.	17	7	15	9	5.8	.0	.0
Miami	25	124	168	29.95	29.98	-.04	82.6	+1.2	90	13	87	70	22	78	17	77	75	78	12.52	+6.4	16	6,679	se.	25	se.	3	5	12	14	6.7	.0	.0
Tampa	35	88	197	29.94	29.97	-.03	82.6	+1.1	94	26	91	70	9	74	23	75	73	81	6.75	-1.4	14	6,430	e.	43	se.	2	3	20	8	5.7	.0	.0
Titusville	44	5	25	29.93	29.98		80.6		94	27	89	68	15	72	22				6.84		16		w.								.0	.0
East Gulf States							80.5	+0.7										78	3.12	-2.2										5.4		
Atlanta	1,173	190	198	28.79	30.00	-.01	77.4	+.4	93	26	86	62	30	69	24	70	67	78	1.81	-2.6	10	6,017	w.	28	nw.	1	3	18	10	6.1	.0	.0
Macon	370	76	84	29.60	29.99	-.02	80.1	+.2	96	9	90	64	15	71	30	72	69	75	3.70	-.6	13	4,511	sw.	30	nw.	13	2	22	7	5.8	.0	.0
Thomasville	273	49	58	29.70	29.99	-.01	80.6	-.4	97	30	90	67	23	72	25	74	72		4.82		16		e.								.0	.0
Apalachicola	36	11	51	29.93	29.97		81.4		92	14	87	70	2	76	16	76			2.20	-5.4	9		ne.								.0	.0
Pensacola	56	149	185	29.93	29.98	.00	81.4	+.5	90	21	86	72	5	76	16	76	74	81	1.87	-6.2	10	7,329	ne.	23	e.	15	10	18	3	4.6	.0	.0
Anniston	741	9	57				77.8	+2.4	94	9	89	58	24	67	36				5.91		10		w.				4	20	7		.0	.0
Birmingham	700	11	48	29.24	29.99	.00	79.8	+.6	95	20	90	65	16	70	29	71	68	77	5.23	+1.0	11	3,798	e.	17	s.	18	7	16	8	5.6	.0	.0
Mobile	57	125	161	29.91	29.97	-.01	82.2	+1.2	93	20	89	70	18	75	20	75	73	79	1.94	-5.0	6	5,470	sw.	21	s.	9	14	8	9	5.2	.0	.0
Montgomery	218	92	105	29.75	29.99	.00	81.6	+.8	94	9	90	68	19	73	22	73	71	77	3.02	-1.2	10	4,187	sw.	24	sw.	29	11	10	10	5.4	.0	.0
Meridian	375	87	95	29.59	29.97	-.01	80.4	+.9	95	28	89	66	19	71	23	73	70	78	1.56	-3.0	11	3,341	sw.	24	se.	24	14	11	6	4.3	.0	.0
Vicksburg	247	65	73	29.72	29.97	-.01	80.6	-.2	94	2	89	67	19	72	23	73	71	79	2.64	-.8	9	4,041	w.	21	nw.	12	6	18	7	5.5	.0	.0
New Orleans	53	76	84	29.91	29.96	-.02	83.6	+1.4	94	27	90	71	17	77	17	75	73	76	7.28	+1.5	15	4,192	se.	18	e.	2	5	15	11	6.0	.0	.0
West Gulf States							82.0	0.0										76	3.50	+0.3										4.6		
Shreveport	249	92	227	29.70	29.96	-.01	83.0	+1.0	95	27	92	69	15	74	23	75	73	79	2.19	-.5	9	5,235	e.	33	ne.	14	14	14	3	4.2	.0	.0
Bentonville	1,303	11	44	28.62	29.95	-.02	76.2	-.3	93	10	86	59	31	67	29				6.82		8	3,195	sw.	12	se.	12	5	13	13		.0	.0
Fort Smith	457	79	94	29.48	29.95	-.02	80.6	+.1	97	10	90	65	16	72	27	72	69	75	6.19	+2.9	11	4,749	e.	24	sw.	12	5	14	12	6.4	.0	.0
Little Rock	357	94	102	29.60	29.97	-.01	79.2	-.6	95	10	88	65	16	71	25	72	69	76	6.54	+2.8	8	4,425	e.	23	sw.	14	11	8	12	5.5	.0	.0
Austin	605	136	148	29.31	29.94		83.8	.0	101	23	94	71	16	74	26	73	70	71	.93	-1.1	6	4,603	s.	27	nw.	24	13	14	4	4.0	.0	.0
Brownsville	57	88	96		29.87		81.9	-2.0	94	24		72	10		20			84	8.06	+5.5	9		e.	66	n.	4	16	8	7		.0	.0
Corpus Christi	20	11	78	29.92	29.94	+.01	83.1	+.6	93	3	89	74	4	78	16	77	75	80	2.27	.0	7	7,232	se.	35	e.	4	13	9	9	4.9	.0	.0
Dallas	512	220	227	29.39	29.93		83.2		97	14	92	69	15	74	23	73	69	69	1.18	-1.6	5	6,473	se.	31	s.	15	17	10	4	3.4	.0	.0
Fort Worth	670	106	114	29.25	29.95	+.01	83.3	+.3	98	7	93	66	15	74	24				2.25	-.4	6	5,664	se.	26	s.	15	15	15	1	3.2	.0	.0
Galveston	54	106	114	29.89	29.95	-.01	83.6	+.6	93	23	88	74	15	79	13	76	74	77	2.06	-2.2	11	6,212	s.	27	se.	4	15	11	5	4.3	.0	.0
Houston	138	292	314	29.81	29.95		83.0	-.2	94	13	91	68	15	75	23				6.36	+2.2	13	6,188	s.	30	se.	7	4	22	5	5.4	.0	.0
Palestine	510	64	72	29.44	29.96	-.01	83.0	+1.2	97	14	93	67	18	73	30	73	70	73	.63	-1.5	6	4,439	s.	32	nw.	14	14	13	4	4.5	.0	.0
Port Arthur	34	58	66	29.91	29.95		83.7		95	28	91	72	6	77	21	76	74	79	4.02	-2.0	12	4,478	s.	24	ne.	14	12	18	1	4.4	.0	.0
San Antonio	693	242	301	29.22	29.92	-.01	83.2	-.3	98	23	93	68	15	74	27	73	70	73	2.78	+.4	7	7,044	se.	34	se.	5	10	15	6	4.9	.0	.0

TABLE 1.—*Climatological data for Weather Bureau stations, August 1933*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							74.6	−0.4										72	4.15	+0.7										5.2		
Chattanooga	762	190	215	29.21	30.00	0.00	76.8	−0.7	92	10	85	62	16	68	24	69	66	75	8.21	+4.2	11	4,060	sw.	30	w.	28	8	12	11	5.7	0.0	0.0
Knoxville	995	79	97	28.97	30.00	−.01	76.8	+.6	93	2	86	62	19	68	26	68	65	76	8.72	+4.8	12	3,901	ne.	22	sw.	2	9	14	8	5.5	.0	.0
Memphis	399	78	86	29.56	29.97	−.01	79.2	−.2	93	1	87	66	15	72	21	71	68	74	2.01	−1.4	8	4,164	e.	24	w.	3	11	13	7	4.8	.0	.0
Nashville	546	168	191	29.43	30.01	+.01	76.8	−1.0	93	12	87	58	16	67	29	69	65	72	2.79	−.9	9	5,057	w.	28	nw.	18	9	16	6	5.0	.0	.0
Lexington	989	193	230				73.3	−1.2	92	27	84	52	15	63	29				3.02		10		e.				13	9	9		.0	.0
Louisville	525	188	234	29.44	30.02	+.02	75.4	−1.6	93	27	85	59	15	66	26	66	62	69	2.17	−1.2	9	6,392	n.	32	e.	21	11	10	10	5.3	.0	.0
Evansville	431	76	116	29.53	29.99	.00	76.7	−.7	92	1	86	61	15	68	25	67	63	68	2.27	−1.1	6	5,412	ne.	27	sw.	2	13	12	6	4.6	.0	.0
Indianapolis	822	194	230	29.13	30.00	.00	73.5	−.2	93	2	84	55	19	64	29	63	58	64	1.97	−1.3	8	7,024	ne.	24	sw.	11	8	16	7	5.1	.0	.0
Terre Haute	575	96	129	29.39	30.00		74.5		94	1	85	55	19	64	27	64	59	65	3.60	+.4	8	6,031	ne.	21	e.	1	17	8	6	4.1	.0	.0
Cincinnati	627	11	51	29.34	30.00	−.01	74.6	+1.0	98	1	86	56	15	63	30	65	61	70	2.79	−.6	11	4,776	ne.	21	w.	2	14	9	8	4.5	.0	.0
Columbus	822	216	230	29.14	30.00	−.01	73.4	+.4	95	1	83	58	29	64	25	64	60	67	2.07	−1.2	9	6,998	ne.	32	se.	31	10	14	7	5.0	.0	.0
Elkins	1,947	59	67	28.03	30.03	+.01	67.9	−1.2	85	13	78	47	30	58	30	62	61	87	5.71	+1.8	14	3,586	se.	25	nw.	3	3	12	16	6.8	.0	.0
Parkersburg	637	77	82	29.39	30.04	+.03	73.6	−.3	96	1	83	57	30	64	28	66	64	78	6.17	+2.7	13	4,050	se.	29	nw.	1	12	10	9	5.3	.0	.0
Pittsburgh	842	353	410	29.12	30.01	.00	72.4	−.5	93	1	81	54	29	64	25	63	59	69	5.51	+2.3	11	6,770	sw.	42	nw.	3	10	12	9	5.4	.0	.0
Lower Lake Region							70.0	+0.4										67	3.10	+0.1										4.7		
Buffalo	767	243	280	29.18	29.99	.00	68.8	+.2	82	6	75	55	29	62	24	62	57	70	2.41	−.7	9	9,067	sw.	34	sw.	7	11	13	7	4.8	.0	.0
Canton	448	10	61	29.51	29.98		66.4	−1.4	91	1	78	44	6	55	37				3.27	−.4	10	5,356	w.	28	e.	24	9	10	12	5.7	.0	.0
Ithaca	836	74	100	29.12	30.00		68.4	−.2	94	1	79	49	30	58	34	61	58	75	5.38	+2.0	13	5,588	nw.	25	ne.	23	9	7	15	6.2	.0	.0
Oswego	335	71	85	29.63	29.99	.00	68.6	+.2	94	1	76	53	30	61	25	62	58	71	4.31	+1.7	13	6,102	s.	26	nw.	13	12	5	14	5.3	.0	.0
Rochester	523	86	102	29.45	30.01	+.02	70.3	+1.1	96	1	79	52	30	62	27	62	56	64	3.76	+.9	11	5,493	nw.	28	w.	1	15	6	10	4.9	.0	.0
Syracuse	596	65	79	29.37	30.00	+.01	70.1	+1.5	96	1	79	53	30	61	28				4.36	+1.5	13	5,042	s.	21	nw.	25	9	10	12	6.0	.0	.0
Erie	714	130	166	29.25	30.00	−.01	70.2	+.6	88	1	78	55	29	63	24	63	59	68	2.45	−.8	5	8,487	nw.	32	n.	24	20	7	4	3.3	.0	.0
Cleveland	762	267	337	29.19	30.00	−.01	71.4	+1.4	88	1	78	60	30	65	22	62	57	63	1.98	−.8	3	8,961	n.	39	w.	1	18	7	6	3.8	.0	.0
Sandusky	629	5	67	29.35	30.02	+.01	72.6	+.8	97	1	81	55	15	64	27				1.68	−1.5	5	5,848	ne.	26	w.	1	10	18	3	4.2	.0	.0
Toledo	628	79	87	29.35	30.02	+.02	70.9	−.4	90	25	80	55	4	62	24	63	58	67	2.99	+.1	6	6,014	e.	24	nw.	1	21	8	2	2.5	.0	.0
Fort Wayne	857	69	84	29.10	30.01		70.8	−.3	88	25	81	53	19	60	28	62	57	65	2.43	−.7	9	5,384	ne.	21	sw.	11	12	13	6	4.6	.0	.0
Detroit	730	218	258	29.25	30.02	+.01	72.0	+1.7	90	25	80	55	20	64	23	62	57	63	2.24	−.5	7	6,613	ne.	28	sw.	7	9	17	5	4.6	.0	.0
Upper Lake Region							67.0	+0.7										70	1.22	−1.7										4.0		
Alpena	609	13	89	29.37	30.04	+.04	64.8	+.7	86	16	75	45	19	54	30	59	56	75	.76	−2.1	5	6,962	nw.	27	nw.	17	19	10	2	3.1	.0	.0
Escanaba	612	54	60	29.38	30.03	+.04	65.0	+.7	92	7	74	46	27	56	26	58	54	72	1.32	−1.9	6	6,513	s.	22	s.	16	13	13	5	3.6	.0	.0
Grand Haven	632	54	89																													
Grand Rapids	707	70	244	29.27	30.03	+.03	70.2	+.5	87	12	81	48	19	59	31	61	55	63	1.41	−1.2	7	7,122	ne.	30	sw.	16	16	10	5	3.8	.0	.0
Lansing	878	6	88	29.09	30.02		67.5	−1.0	88	25	80	45	19	55	32	61	57	73	2.14	−.7	7	5,432	n.	19	w.	11	11	18	2	4.7	.0	.0
Ludington	637	60	66																													
Marquette	734	77	111	29.22	30.02	+.04	65.3	+1.5	87	7	74	48	3	57	27	58	53	68	.80	−1.9	6	7,122	w.	31	s.	16	13	12	6	4.7	.0	.0
Sault Sainte Marie	614	11	52	29.35	30.03	+.04	64.0	+1.9	87	23	74	46	19	54	34	57	53	73	.82	−1.8	6	5,028	nw.	24	nw.	26	19	8	4	3.5	.0	.0
Chicago	673	7	131	29.31	30.03	+.03	71.4	−.2	91	12	78	56	19	65	23	63	59	70	1.14	−2.1	7	6,825	ne.	30	nw.	17	16	10	5	4.0	.0	.0
Green Bay	617	109	141	29.36	30.02	+.03	68.2	+.5	90	7	79	49	29	58	30	59	54	66	1.10	−2.1	4	6,382	s.	25	s.	11	14	11	6	4.3	.0	.0
Milwaukee	681	97	221	29.30	30.03	+.03	70.0	+.8	85	16	77	55	29	63	21	62	57	67	1.75	−.9	6	8,027	w.	33	nw.	17	17	9	5	3.4	.0	.0
Duluth	1,133	5	47	28.80	30.01	+.04	64.0	+1.4	85	6	74	46	3	54	30	57	53	74	.99	−2.2	4	7,767	ne.	27	nw.	25	15	11	5	4.4	.0	.0
North Dakota							69.2	+3.1										55	0.62	−1.6										4.0		
Moorhead	940	50	58	28.97	29.97	+.01	69.5	+3.4	97	8	82	45	28	57	39	58	50	55	1.34	−1.6	9	6,173	s.	24	s.	31	12	13	6	4.2	.0	.0
Bismarck	1,674	8	57	28.20	29.96	+.02	69.3	+2.0	96	9	83	40	28	56	39	57	48	56	.48	−1.3	7	6,426	se.	28	se.	31	17	8	6	4.0	.0	.0
Devils Lake	1,478	11	44	28.42	29.97	+.03	68.2	+3.4	96	8	82	40	28	54	38	56	48	56	.27	−2.2	7	6,290	s.	24	se.	31	14	11	6	3.9	.0	.0
Grand Forks	833	12	67				69.5		97	9	84	39	28	55	42	58			.46		2		nw.	30	se.	30	7	19	5	4.2	.0	.0
Williston	1,878	41	48	27.99	29.92	−.01	69.6	+3.5	99	5	82	44	1	57	39	57	48	53	.41	−1.1	7	5,317	se.	36	w.	31	18	7	6	3.8	.0	.0
Upper Mississippi Valley							72.5	−0.3										66	2.08	−1.2										4.6		
Minneapolis	918	102	208	29.04	30.01		70.8	+.9	93	10	81	50	28	60	30	59	51	55	1.09	−2.0	5	7,111	s.	25	nw.	17	14	12	5	4.1	.0	.0
La Crosse	714	11	48	29.24	30.00	+.02	69.2	−.8	90	7	82	48	14	57	38	60	55	69	1.34	−2.4	4	3,030	s.	14	s.	6	19	7	5	3.5	.0	.0
Madison	974	70	78	28.99	30.02	+.03	69.6	−.2	86	7	79	52	19	60	27	60	55	66	2.57	−.6	5	5,217	se.	22	ne.	2	19	8	4	3.6	.0	.0
Charles City	1,015	10	51	28.96	30.02	+.05	69.0	−.1	91	8	81	48	30	57	37	60	55	65	1.40	−2.1	7	4,074	se.	18	s.	15	15	8	8	4.8	.0	.0
Davenport	606	118	143	29.36	30.02	+.04	72.8	−.3	89	1	83	55	18	63	28	63	58	66	2.51	−1.0	9	5,356	e.	37	nw.	17	10	13	8	5.4	.0	.0
Des Moines	861	5	99	29.11	30.00	+.03	71.8	−1.3	92	7	82	53	30	62	29	63	58	68	1.85	−1.7	7	5,774	se.	24	nw.	12	10	7	14	5.9	.0	.0
Dubuque	700	81	96	29.28	30.02	+.04	70.5	−1.2	90	7	81	52	19	60	33	61	56	64	2.32	−.9	4	4,102	n.	23	sw.	17	14	11	6	4.4	.0	.0
Keokuk	614	64	78	29.36	30.02	+.04	74.0	−1.0	91	7	83	56	19	65	26	64	60	66	1.83	−1.4	8	4,544	e.	20	nw.	12	9	10	12	5.7	.0	.0
Cairo	358	87	93	29.60	29.97	−.02	76.8	−1.0	92	1	85	63	16	69	23	69	66	75	4.41	+1.4	7	4,635	ne.	25	se.	27	11	10	10	5.3	.0	.0
Peoria	609	11	45	29.37	30.03	+.04	73.0	+.5	93	12	84	52	14	62	34	64	59	71	2.66	−.5	7	3,747	ne.	21	s.	2	14	12	5	3.9	.0	.0
Springfield, Ill	636	5	191	29.33	30.00	+.01	75.2	+.7	96	12	86	56	19	65	29	65	60	65	2.34	−.8	11	6,937	ne.	40	sw.	2	13	11	7	4.5	.0	.0
St. Louis	568	265	303	29.39	29.98	−.01	77.8	+.5	99	12	87	61	19	68	29	66	60	60	.60	−2.4	6	6,692	ne.	23	sw.	2	13	11	7	4.2	.0	.0
Missouri Valley							73.9	−0.4										67	3.68	+0.3										5.3		
Columbia, Mo	784	6	84	29.18	29.99	+.02	75.3	−.3	96	12	85	56	14	65	31				2.86	−.7	10	4,872	n.	23	sw.	2	14	12	5	4.4	.0	.0
Kansas City	963	10	86	28.97	29.98	+.01	76.2	−.4	95	9	84	56	30	68	25	67	62	68	4.00	−.1	11	5,628	e.	30	nw.	16	7	10	14	6.3	.0	.0
St. Joseph	967	11	49	28.97	29.97		75.0		94	9	84	54	30	66	29	66	62	70	5.09	+1.6	11	5,255	se.	20	se.	20	12	8	11	5.4	.0	.0
Springfield, Mo	1,324	98	104	28.61	29.99	+.02	74.7	−1.0	90	10	83	59	30	66	25	67	64	72	4.86	+.8	12	5,631	se.	24	n.	2	15	9	7	4.3	.0	.0
Iola	984	11	50	28.94	29.96	.00	77.1	.0	99	7	88	54	30	67	29				7.37	+3.9	14		n.				7	10	14		.0	.0
Topeka	987	92	107				76.2	.0	100	7	86	54	30	66	34				3.50	−.6	11	5,869	s.	30	s.	2	9	13	9	5.5	.0	.0
Lincoln	1,189	11	81	28.74	29.97	+.02	73.6	−.8	101	6	84	54	18	64	33	65	60	70	4.32	+.8	8	6,030	e.	28	nw.	15	7	9	15	6.3	.0	.0
Omaha	1,105	115	122	28.84	29.99	+.03	73.6	−.8	100	6	83	54	30	64	28	64	58	66	1.63	−1.4	10	5,024	n.	20	n.	2	8	10	13	6.1	.0	.0
Valentine	2,598	47	54	27.33	30.01	+.07	69.8	−1.9	98	11	82	46	3	58	35	59	53	65	2.88	+.7	14	6,447	s.	27	sw.	15	10	12	9	5.1	.0	.0
Sioux City	1,135	94	164	28.79	29.98	+.03	71.5	−.5	95	11	82	52	18	62	33	62	56	64	1.74	−1.4	9	7,342	s.	35	nw.	15	11	7	13	5.7	.0	.0
Huron	1,306	59	74	28.62	29.99	+.04	71.0	+1.6	101	6	83	49	18	59	41	60	53	60	2.22	−.2	7	6,682	se.	26	nw.	15	14	11	6	4.3	.0	.0
Northern Slope							66.7	+0.4										55	2.37	+1.2										4.6		
Billings	3,140	5					69.6		102	14	88	40	22	52	50				3.86		8		nw.				15	10	6		.0	.0
Havre	2,505	11	67	27.36	29.95	+.04	68.7	+3.3	98	18	83	47	26	55	45	55	46	55	3.90	+2.7	10	6,381	e.	35	sw.	5	18	7	6	3.6	.0	.0
Helena	4,124	85	111	25.84	29.96	+.02	65.3	+.3	94	14	77	38	21	53	35	52	41	50	3.06	+2.3	6	6,132	sw.	35	s.	3	9	13	9	5.2	.0	.0
Kalispell	2,973	48	56	26.95	29.95	+.02	64.6	+1.8	91	14	79	39	26	50	39	53	43	55	1.77	+.9	9	4,948	nw.	27	w.	29	17	7	7	3.8	.0	.0
Miles City	2,371	48	55		29.96	+.03	71.7	+.2	100	4	84	50	24	59	41			49	1.38	+.3	8	4,721	se.	23	n.	24	17	9	5		.0	.0
Rapid City	3,259	50	58	26.65	29.99	+.06	69.0	−.5	96	5	80	51	24	58	33	58	50	56	3.00	+1.3	9	5,836	w.	26	ne.	15	12	12	7	4.7	.0	.0
Cheyenne	6,088	84	101	24.11	29.95	+.03	65.0	−.6	87	15	77	45	24	53	31	53	46	58	2.02	+.5	12	7,027	s.	30	w.	21	8	13	10	5.7	.0	.0
Lander	5,372	60	68	24.71	29.94	+.02	65.5	.0	93	12	80	39	23	51	44	51	40	47	1.67	+1.1	6	3,924	sw.	26	sw.	8	19	8	4	3.2	.0	.0
Sheridan	3,790	10	47	26.13	29.96		66.6		97	5	83	41	24	51	48	54	45	57	1.01	+.1	8	3,633	nw.	24	sw.	10	17	8	6	4.1	.0	.0
Yellowstone Park	6,241	11	48	23.99	30.00	+.07	58.9	−2.0	87	14	73	35	21	44	40	46	36	52	2.58	+1.5	10	5,770	sw.	27	sw.	30	12	12	7	4.6	T	.0
North Platte	2,821	11	51	27.10	29.98	+.04	71.6	+.8	96	11	82	56	24	61	35	62	59	73	3.35	+1.0	14	5,113	se.	22	w.	11	6	13	12	6.2	.0	.0

TABLE 1.—*Climatological data for Weather Bureau Stations, August 1933*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Middle Slope							**75.6**	**-0.4**										**64**	**4.06**	**+1.6**										**5.0**		
Denver	5,292	106	113	24.80	29.94	+0.02	70.6	-0.1	91	15	82	50	28	59	33	56	48	53	0.84	-0.6	10	5,543	s.	25	ne.	16	10	17	4	4.8	0.0	0.0
Pueblo	4,685	80	86	25.35	29.95	+.04	72.6	-.1	93	9	86	52	28	60	36	50	52	60	1.57	-.2	9	4,923	e.	38	n.	9	8	20	3	4.9	.0	.0
Concordia	1,392	50	58	28.54	29.98	+.03	76.4	-.1	104	6	87	56	30	66	31	66	61	66	3.30	+.4	8	5,205	e.	20	sw.	6	7	15	9	5.7	.0	.0
Dodge City	2,509	10	86	27.42	29.96	+.03	76.8	-.9	102	9	88	58	30	66	31	65	59	62	4.79	+2.1	12	8,176	s.	30	e.	13	19	5	7	3.7	.0	.0
Wichita	1,358	85	93	28.54	29.94	-.01	78.2	-.1	104	9	88	57	30	68	29	68	63	69	8.50	+5.4	12	7,218	s.	28	s.	16	10	13	8	5.4	.0	.0
Oklahoma City	1,214	10	47	28.69	29.93	-.01	78.9	-.8	97	10	88	62	31	70	26	71	68	76	5.38	+2.5	11	5,969	s.	27	se.	20	8	13	10	5.5	.0	.0
Southern Slope							**80.9**	**+1.3**										**60**	**2.60**	**+0.3**										**4.7**		
Abilene	1,738	10	52	28.15	29.91	-.01	84.4	+2.4	101	14	96	66	30	73	29	69	62	57	.60	-1.6	6	6,195	s.	21	s.	20	12	10	9	5.0	.0	.0
Amarillo	3,676	10	49	26.29	29.93	+.01	77.2	+1.5	101	9	89	60	30	66	31	64	58	63	6.02	+2.9	14	6,911	s.	24	s.	22	11	17	3	4.7	.0	.0
Big Spring	2,537	5	62	27.36	29.91	-----	81.2	-----	100	20	92	64	26	70	29	67	60	57	5.99		6	-----	s.	-----	-----	-----	10	14	7	5.1	.0	.0
Del Rio	944	64	71	28.90	29.86	-.04	84.2	.0	98	24	93	70	16	75	24	72	66	61	.49	-1.2	7	7,271	se.	25	se.	5	11	16	4	4.5	.0	.0
Roswell	3,566	75	85	26.38	29.90	+.02	77.8	+1.2	97	9	90	61	26	66	31	64	57	60	3.28	+1.1	9	5,342	s.	36	nw.	15	11	17	3	4.1	.0	.0
Southern Plateau							**79.6**	**+2.2**										**51**	**0.57**	**-0.5**										**3.5**		
El Paso	3,778	152	175	26.16	29.83	-.01	82.0	+2.8	99	16	93	66	26	71	27	64	55	47	.27	-1.4	5	6,238	e.	45	ne.	17	14	11	6	4.2	.0	.0
Albuquerque	4,972	51	66	25.09	29.85	-----	73.4	-----	93	15	87	53	26	60	33	60	54	60	2.42	-----	12	5,322	n.	35	nw.	27	11	18	2	4.5	.0	.0
Santa Fe	7,013	38	53	23.37	29.89	.00	67.8	+.4	87	10	79	50	26	56	28	54	47	56	1.90	-.4	15	4,137	e.	25	ne.	17	6	22	3	4.9	.0	.0
Flagstaff	6,907	10	59	23.45	29.85	+.01	65.0	+2.2	89	12	80	43	29	50	41	52	-----	61	1.90	-----	12	5,357	n.	30	nw.	20	1	20	10	-----	.0	.0
Phoenix	1,108	10	107	28.63	29.74	-.05	92.4	+3.9	115	10	105	71	28	80	34	69	57	37	.38	-.6	6	4,566	e.	27	s.	21	20	9	2	2.8	.0	.0
Yuma	141	9	54	29.58	29.72	-.04	92.0	+1.6	119	10	107	67	29	78	40	72	63	46	.27	-.2	1	4,193	sw.	25	e.	10	29	1	1	1.2	.0	.0
Independence	3,957	5	26	25.94	29.89	+.08	78.4	+2.3	106	14	95	53	5	62	38	55	-----	-----	.02	-.1	1	-----	s.	14	s.	12	24	3	4	-----	.0	.0
Middle Plateau							**72.5**	**+1.5**										**32**	**0.60**	**-0.1**										**2.2**		
Reno	4,532	74	81	25.48	29.88	+.04	72.3	+5.3	103	13	90	45	30	54	44	52	36	35	.79	+.6	2	5,353	w.	29	sw.	29	27	3	1	1.5	.0	.0
Tonopah	6,090	12	20	-----	-----		73.4	-----	96	12	85	53	26	62	26	51	32	25	.01		1		se.	-----	-----	-----	-----	-----	-----	-----	.0	.0
Winnemucca	4,344	18	56	25.61	29.92	+.04	70.4	+1.1	104	12	90	36	26	51	55	49	31	30	.09	-.1	2	5,229	sw.	21	s.	16	28	2	1	.9	.0	.0
Modena	5,473	10	46	24.64	29.86	.00	69.6	+.4	98	13	86	45	30	53	44	52	37	39	1.49	+.2	6	7,256	sw.	47	w.	7	17	12	2	3.0	.0	.0
Salt Lake City	4,360	86	210	25.62	29.89	-.02	74.0	-.5	99	14	87	47	22	61	35	54	37	30	.20	-.6	3	5,587	s.	34	sw.	20	23	7	1	2.0	.0	.0
Grand Junction	4,602	60	68	25.38	29.88	-.02	76.4	+1.0	100	13	90	51	28	63	38	56	41	36	.43	-.7	7	5,166	se.	27	s.	26	18	8	5	3.5	.0	.0
Northern Plateau							**71.3**	**+1.9**										**39**	**0.32**	**-0.1**										**2.6**		
Baker	3,471	48	53	26.46	29.99	+.04	65.8	+1.2	94	17	82	38	30	50	41	52	40	44	.71	+.2	5	5,009	n.	27	sw.	2	20	8	3	2.7	.0	.0
Boise	2,739	79	87	27.12	29.92	-.01	73.0	+1.2	100	14	88	45	21	58	38	55	40	35	.01	-.2	1	4,143	nw.	20	nw.	20	24	5	2	1.9	.0	.0
Pocatello	4,477	60	68	25.49	29.91	-.01	69.6	.0	100	14	84	42	26	55	40	51	34	35	.25	-.5	4	6,111	se.	25	sw.	20	20	9	2	2.7	.0	.0
Spokane	1,929	101	110	27.93	29.94	-.01	70.3	+2.2	98	10	84	46	21	56	41	55	42	45	.64	.0	5	4,400	sw.	19	w.	29	18	5	8	3.5	.0	.0
Walla Walla	991	57	65	28.86	29.92	-.04	75.2	+2.5	103	15	89	51	25	62	38	57	43	36	.15	-.3	3	4,207	s.	16	w.	29	21	6	4	2.6	.0	.0
Yakima	1,076	58	67	28.80	29.93	-----	73.8	+4.3	102	15	88	51	22	59	37	56	42	39	.16	.0	3	4,811	nw.	21	nw.	20	21	5	5	2.5	.0	.0
North Pacific Coast Region							**64.0**	**+1.9**										**69**	**0.76**	**-0.1**										**4.4**		
North Head	211	11	56	29.80	30.02	-.01	58.1	+.5	87	25	63	50	1	54	34	55	53	90	.65	-.4	11	9,394	n.	33	n.	7	5	5	21	7.9	.0	.0
Seattle	125	90	321	29.86	29.99	-.01	66.8	+3.7	92	26	77	53	21	57	33	59	53	68	1.56	+.9	6	4,992	ne.	18	sw.	5	15	7	9	4.0	.0	.0
Tatoosh Island	86	10	54	29.93	30.02	+.02	55.9	+.6	75	23	60	48	24	52	23	54	53	93	1.22	-.8	9	7,803	s.	28	s.	16	9	6	16	6.5	.0	.0
Medford	1,329	29	58	28.52	29.89	-----	73.4	-----	108	14	92	44	30	55	50	57	45	45	.02	-.2	1	4,389	nw.	25	nw.	3	27	2	2	1.2	.0	.0
Portland, Oreg	153	68	106	29.82	29.97	-.04	69.6	+2.9	102	15	80	52	31	59	36	60	54	64	.86	+.2	5	4,748	nw.	19	ne.	25	15	7	9	4.0	.0	.0
Roseburg	510	75	99	29.42	29.96	-.04	69.6	+1.6	99	14	84	48	21	55	47	58	49	56	.24	-.1	3	3,712	n.	18	n.	20	21	3	7	2.6	.0	.0
Middle Pacific Coast Region							**68.4**	**+1.5**										**64**	**0.01**	**0.0**										**3.2**		
Eureka	62	73	89	29.92	29.99	-.01	55.3	-.7	67	16	60	46	22	51	15	53	52	92	.05	-.1	4	4,545	n.	23	n.	20	5	10	16	6.7	.0	.0
Red Bluff	330	5	58	29.46	29.80	-.06	83.1	+3.5	114	14	99	59	4	67	43	62	45	32	.00	.0	0	4,289	s.	18	se.	3	30	1	0	.5	.0	.0
Sacramento	69	106	117	29.75	29.82	-.03	75.4	+2.5	111	13	92	53	26	59	47	60	49	49	.00	.0	0	6,335	s.	18	sw.	3	30	1	0	.3	.0	.0
San Francisco	155	208	243	29.73	29.90	-.02	59.8	+.7	82	16	66	50	13	53	25	55	53	83	T	.0	0	5,783	sw.	21	sw.	16	11	12	8	5.2	.0	.0
South Pacific Coast Region							**73.0**	**-0.5**										**64**	**0.01**	**0.0**										**2.7**		
Fresno	327	89	98	29.46	29.80	-.02	82.2	+1.5	112	14	98	58	27	66	37	62	47	35	T	.0	0	5,838	nw.	17	nw.	17	30	1	0	.3	.0	.0
Los Angeles	338	159	191	29.52	29.88	.00	70.2	-.9	96	13	79	56	30	61	30	62	59	75	.01	.0	1	4,166	sw.	16	w.	11	16	15	0	2.9	.0	.0
San Diego	87	62	70	29.78	29.87	-.02	66.6	-2.1	80	14	71	58	30	62	17	62	60	83	.01	.0	1	5,174	nw.	15	nw.	15	10	15	6	5.0	.0	.0
West Indies																																
San Juan, P.R	82	9	54	29.88	29.96	-----	81.1	+.6	92	21	86	73	25	76	18	-----	-----	-----	4.42	-1.6	21	8,045	e.	30	e.	14	3	20	8	6.1	.0	.0
Panama Canal																																
Balboa Heights	118	6	97	-----	[1] 29.86	+.03	79.6	-----	92	1	86	70	10	74	17	-----	-----	[1] 87	6.55	-1.3	19	3,802	nw.	26	n.	7	1	11	19	7.8	.0	.0
Cristobal	36	6	97	-----	[1] 29.85	+.01	81.7	-----	91	18	87	73	10	76	15	76	75	[1] 82	8.27	-7.0	18	4,224	se.	24	sw.	4	0	9	22	7.9	.0	.0
Alaska																																
Fairbanks	454	68	87	-----	[2] 29.80	-----	53.8	-----	82	1	64	28	27	44	32	-----	-----	66	2.16	+.2	14	4,317	e.	24	sw.	3	1	8	22	-----	.0	.0
Juneau	80	11	50	[2] 29.91	[2] 30.00	-----	55.2	-----	80	2	61	42	23	49	30	52	49	83	11.72	-----	20	4,282	s.	22	se.	17	7	3	21	7.4	.0	.0
Hawaiian Islands																																
Honolulu	38	86	100	[2] 30.03	[2] 30.07	-----	75.9	+2.5	82	23	80	69	25	71	12	69	66	73	.61	-.7	13	7,286	e.	24	ne.	2	9	20	2	4.8	.0	.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

Table 2.—*Data furnished by the Canadian Meteorological Service*

AUGUST 1933

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*In.*	*In.*	*In.*
Cape Race, N.F	99												
Sydney, C.B.I	48	29.96	30.01	+0.06	65.2	+1.9	75.0	55.3	86	42	4.28	+0.66	0.0
Halifax, N.S	88												
Yarmouth, N.S	65	29.90	29.97	.00	62.6	+2.4	70.7	54.5	77	43	3.64	+.02	.0
Charlottetown, P.E.I	38	29.92	29.96	+.02	66.4	+2.1	73.5	59.3	85	49	3.08	−.66	.0
Chatham, N.B	28	29.85	29.88	−.05	65.2	+2.0	77.5	52.9	93	39	2.60	−1.44	.0
Father Point, Que	20	29.90	29.92	+.01	56.4	+.8	64.2	48.5	83	40	2.74	−.31	.0
Quebec, Que	296	29.67	29.97	+.04	64.6	+1.5	73.3	55.9	83	46	5.18	+1.35	.0
Doucet, Que	1,236				58.4		73.7	43.1	86	28	2.17		.0
Montreal, Que	187												
Ottawa, Ont	236	29.72	29.98	+.02	68.2	+3.4	79.5	56.8	89	48	4.17	+1.14	.0
Kingston, Ont	285	29.68	29.98	.00	68.7	+1.7	76.8	60.6	87	52	4.06	+1.68	.0
Toronto, Ont	379	29.60	29.99	.00	69.1	+3.1	78.9	59.3	94	52	2.41	−.35	.0
Cochrane, Ont	930				62.2		73.5	51.0	88	41	1.87		.0
White River, Ont	1,244	28.69	29.99	+.03	57.7	+1.3	72.7	42.7	84	28	1.99	−1.31	.0
London, Ont	808				67.2		79.2	55.2	90	45	1.88		.0
Southampton, Ont	656	29.31	30.02	+.03	66.6	+2.8	77.0	56.1	86	45	.93	−1.32	.0
Parry Sound, Ont	688	29.32	30.00	+.02	66.8	+3.3	77.1	56.4	84	43	3.02	+.30	.0
Port Arthur, Ont	644	29.29	30.00	+.04	62.6	+3.1	73.7	51.5	82	40	1.63	−1.12	.0
Winnipeg, Man	760												
Minnedosa, Man	1,690	28.18	29.96	+.02	64.2	+4.8	77.7	50.6	94	36	2.90	+.80	.0
Le Pas, Man	860				63.8		76.5	51.2	85	42	2.24		.0
Qu'Appelle, Sask	2,115												
Moose Jaw, Sask	1,759				66.5		80.4	52.5	94	38	3.03		.0
Swift Current, Sask	2,392												
Medicine Hat, Alb	2,365	27.45	29.89	−.03	67.2	+1.5	81.4	53.1	98	40	1.28	−.39	.0
Calgary, Alb	3,540	26.33	29.94	+.03	61.5	+2.1	74.9	48.0	92	36	2.74	+.60	.0
Banff, Alb	4,521												
Prince Albert, Sask	1,450	28.43	29.98	+.06	64.4	+5.5	77.6	51.2	92	38	1.74	−.41	.0
Battleford, Sask	1,592												
Edmonton, Alb	2,150												
Kamloops, B.C	1,262												
Victoria, B.C	230	29.74	29.99	−.02	62.2	+3.5	70.5	53.8	91	50	.35	−.25	.0
Barkerville, B.C	4,180												
Estevan Point, B.C	20												
Prince Rupert, B.C	170												
Hamilton, Ber	151												

LATE REPORTS FOR JULY 1933

Cape Race, N.F	99				53.5		61.8	45.1	80	36	2.78		0.0
Calgary, Alb	3,540	26.27	29.87	−.03	62.2	+1.6	76.9	47.7	97	37	.52	−2.16	.0
Victoria, B.C	230	29.81	30.06	+.01	58.5	−1.5	66.2	50.8	81	48	1.13	+.73	.0

SEVERE LOCAL STORMS, AUGUST 1933

[Compiled by Mary O. Souder]

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Phoenix, Mesa, Tempe, and Chandler, Ariz.	1				$4,500	Wind	Money value represents cost of telephone poles and wires to be replaced.	Official, U.S. Weather.
Fulton, N.Y.	1				10,000	Electrical	Light and telephone systems damaged; barn with contents destroyed by fire after being struck by lightning; trees uprooted; property damaged.	Do.
Steuben and Yates Counties, N.Y.	1					Thunderstorm	Considerable damage to telephone and power lines; trees uprooted.	Do.
Springvale (near), Tenn.	1				10,000	Thunderstorm, heavy rain and hail.	Damage to State fish hatchery	Do.
St. Joseph, Mo., 8 miles south.	2	4:15 p.m.			350	Tornado and heavy hail.	20 acres of corn destroyed; path narrow and not continuous.	Do.
Canon City, Colo.	2	6 p.m.	[1] 6			Hail	Thousands of dollars loss to crops and gardens; considerable property damage.	Do.
Bellview, N.Mex.	2	P.m.	[1] 2			do	Much damage to crops	Do.
Lancaster (near), S.C.	2	do		1		Thunderstorm	1 person killed by lightning	Do.
Idaho County, Idaho	3-4	P.m.	[1] 6		50,000	Hail, wind, and rain.	Severe crop loss except in places where grains had been cut; gardens ruined; fences washed away by high water.	Do.
East Selah, Wash.	4	5 p.m.	[1] 1		4,000	Hail and rain	Damage to fruit trees	Do.
Winnsboro, S.C.	4	7 p.m.			500	Thunderstorm	Church tower damaged by lightning	Do.
York and Dauphin Counties, Pa.	4	P.m.		1	20,000	Severe electrical	Lightning caused 2 fires and 1 death	Do.
St. Paul, S.C.	4	do			2,000	Thunderstorm	Schoolhouse struck by lightning and burned	Do.
Moiese-Polson, Mont.	4		880-1,760		7,500	Hail	Damage severe in spots	Do.
Old Hickory, Tenn.	4					Heavy rain	Small child washed through a sewer pipe and drowned while playing in the street.	Do.
Brownsville, Tex., and vicinity.	4-5	P.m.		1	500,000	Hurricane	Citrus growers were heaviest losers; loss to cotton crop; 2 small hangars at the Pan-American Airport blown away; other property damage.	Do.
Miami, Ariz.	6-7				1,000	Wind and rain	Damage to roofs and awnings	Do.
Tucson, Ariz.	9	3 p.m.			2,000	Thundersquall	Trees blown down; property damaged	Do.
Mattoon, Ill., vicinity of.	9					Heavy rain, electrical.	Trees and corn blown down; other damage	Do.
Lewistown, Md.	10	8:30 a.m.	25			Tornado	Several outbuildings demolished; large plate glass window smashed.	Do.
Chester, Ill.	10				4,000	Heavy rain, electrical.	Man injured by lightning; damage to highway construction work by flooding; trees and corn blown down.	Do.
Clear Lake and Glenwood City, Wis., vicinity of.	10		50	1	25,000	2 tornadoes	2 persons injured by flying timbers; several buildings damaged; trees uprooted; path 20 miles long.	Do.
Rothschild and Rest Lake, Wis.	10				5,200	Thunderstorm	Property damaged	Do.
Merrill, Wis.	10					Hail	Much damage to gardens; some property loss	Do.
Otwell, Ind.	12	4-5 p.m.	440		10,000	Tornado	Damage to buildings; other property loss; path 880 yards long.	Do.
Charleston, S.C.	12	7 p.m.			150,000	Electrical	Lightning struck a pile of sisal hemp; chimney of Charleston High School damaged.	Do.
Crossett, Ark.	12			1		Wind	A person injured when a tree fell across a wagon	Do.
Helena, Ark.	12					Wind, rain, and hail.	Considerable damage to plate-glass windows and awnings; trees uprooted; hail caused small damage to gardens and shrubbery.	Do.
Sparta (near), Ill.	13				10,500	Wind and hail	Wind damage chiefly to buildings; loss to corn crop from hail.	Do.
Pittsburgh, Pa., and vicinity.	13					Thunderstorm and hail.	Loss to matured fruits, especially plums and tomatoes.	Do.
Lake Keuka and Lodi, N.Y., and vicinity.	13				100,000	Hail	Large loss to fruit crops and gardens; property damaged.	Do.
Barneston, Nebr.	14	5-6 p.m.	[1] 1		500	do	Property damaged	Do.
Erick, Mayfield, and Beckham, Okla.	14	P.m.			5,000	do	Damage mostly to crops	Do.
Charleston, S.C.	16	A.m.			3,000	Electrical	Huge oil tank struck by lightning	Do.
Pasamonte, N.Mex.	16	3 p.m.	1,320			Hail	Considerable damage to roofs and windows	Do.
Benson, Ariz.	16	5:30 p.m.			3,000	Hail, rain, and wind.	2 barns and 6 tourist cabins wrecked; several roofs damaged; trees blown down.	Do.
Floriston, Calif.	16-17	P.m.			5,000	Heavy rain	Damage to highways, railroad tracks, and industrial plants.	Do.
Miami, N.Mex.	17	2 p.m.	[1] 1		1,200	Hail	Path 4 miles long	Do.
Argyle, Wis., 5 miles northwest.	17					do	Some hailstones are said to have weighed a pound; considerable damage to crops and property.	Do.
Spring Lake Heights, N.J.	18	P.m.				Tornado	Power and electric lines out of commission; 2 garages demolished; trees uprooted.	Do.
Anadarko, Okla.	18		[1] 5		75,000	Hail	Hailstones as large as hen's eggs caused severe loss to crops grown on about 100 farms; property damaged.	Do.
Alexandria (near), Tenn.	18				30,000	Heavy hail	Damage to tobacco crop	Do.
Manassa, Colo.	19	2 p.m.	[1] 4		100,000	Hail	Severe crop damage	Do.
Dodge City, Kans., and vicinity.	19	7:38-11:25 p.m.				Rain, wind, electrical.	Basements flooded; barns damaged; loss not estimated.	Do.
Atlantic City, N.J.	20			7		Wind	Boats capsized causing loss of life; this storm regarded as one of the strangest occurrences ever noted in these waters.	Do.
Chouteau and Cascade Counties, Mont.	20-21			3		Rain and cold	2 members of the Civilian Conservation Corps, in attempting to walk from one camp to another, were caught in the rain of the 20th and perished from exposure on the following day; a child lost on the 20th found dead from exposure on the 21st.	Do.
Tucson, Ariz.	21	5:10 p.m.			10,000	Thundersquall	2 railroad underpasses and several cellars flooded and a culvert and footbridge washed out; trees blown down; other property damaged.	Do.
Butte, Mont.	21					Snowstorm	Trees broken and gardens ruined	Do.
New York, N.Y.	21-22					Rain and wind	Considerable damage resulted from excessive rains in connection with high tides and gales.	Do.
Trenton, N.J.	21-24					Rain and wind	Electric wires blown down; trees uprooted; roofs blown off; considerable damage reported.	Do.
Manzanola, Vroman, and Rocky Ford, Colo.	22	8:30-10:30 p.m.	[1] 3		275,000	Hail	Severe crop damage	Do.

[1] Miles instead of yards.

SEVERE LOCAL STORMS, AUGUST 1933—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
North Carolina, northeastern portion.	22-23				$250,000	Heavy rain and gales.	Much damage to telegraph and telephone lines, houses, highways, and fishing craft; considerable loss to crops, except tobacco which had been gathered.	Official, U.S. Weather.
Tidewater Virginia and north to Washington, D.C.	22-23			15	17,500,000	Hurricane and storm tides.	Waterfront buildings wrecked; wire lines and trees down; windows blown in; fishing equipment destroyed; traffic interrupted; small craft beached; vast damage by unprecedentedly high tides. For more detailed report see p. 233 Monthly Weather Review, this issue.	Do.
New York, southeastern portion.	22-24			1		Heavy rain and wind.	Many streams overflowed; 1 person drowned at Mount Tremper; trees and signs blown down; loss to small grain and fruit crop.	Do.
Pennsylvania, eastern portion.	22-24			4	1,000,000	Heavy rain, wind and flood.	Much loss to property and crops from wind and flooding; at Philadelphia wind velocity reached 42 miles per hour at 5:50 p.m., on the 23d; on the 24th the barometer fell to 29.40 inches, the lowest of record for August; this was the most destructive storm in 45 years.	Do.
Merino, Colo	23	3 p.m.	[1] 2½		10,000	Hail	Considerable damage to crops	Do.
Yuma, Colo	23	5 p.m.	[1] 2		5,000	do	Much loss to crops	Do.
Fleming, Colo	23	P.m.	[1] 6			do	Several thousand dollars' damage to buildings and crops.	Do.
Atlantic City, N.J	23-24				3,000,000	Wind, rain, and floods.	Extreme wind velocity was 76; extreme maximum velocity, 65 miles, was the highest ever recorded at this station for August; slight damage to boardwalks; street flooded.	Do.
Baltimore, Md	23-24					Rain and gale	Cellars flooded; this storm caused the greatest 24-hour precipitation—7.62 inches—ever recorded at Baltimore.	Do.
Claude, Tex	24	12:40 p.m.	33		50,000	Tornado	Wires down; property damaged	Do.
Trenton, Nebr., and vicinity.	24					Heavy rain, flood	2½ miles of Burlington track washed out; many farmers driven from their homes; loss to crops.	Do.
Cheyenne Wells, Colo	25			1		Electrical	A cattleman was killed and a ranch hand seriously injured when lightning struck the chimney of a ranch house.	Do.
Big Spring, Tex	26	12:45 a.m.-11:30 p.m				Thunderstorm	Buildings flooded; field at airport flooded for several hours.	Do.
Ridgeland (near), S.C	26	4-5 p.m.		1		Thundersquall	Man drowned during squall	Do.
Julesburg, Colo	26	P.m.	[1] 2		1,000	Gale	Alfalfa stalks nearly leveled to the ground; loss to hay; considerable damage to chimneys, roofs and glass.	Do.
Holmes County, Ohio	26	do				Electrical	Lightning destroyed a large barn and contents causing loss of several thousands of dollars.	Do.
Mount Pleasant, S.C	26			2		do	Lightning caused 2 deaths and the injury of 1 person.	Do.
Rocky Ford, Colo	27	Noon				Heavy rain and hail.	Severe damage to crops of melons and sugar beets	Do.
Cheyenne, Wyo., and vicinity.	27	12 p.m.			5,000	Rain and hail	Houses flooded causing residents to abandon them for several hours; highways damaged; small loss to crops.	Do.
Kimball, Cheyenne, and Hitchcock Counties, Nebr.	27-28				8,000	Heavy rains	Bridges, highways and railroad tracks washed out; basements flooded.	Do.
Kersey, Colo	29					Electrical	4 persons injured by lightning	Do.
Byers, Colo	31	P.m.	[1] 4-5		50,000	Hail	Considerable crop damage	Do.
Julesburg, Colo	31	do			30,000	do	Loss to farm produce and gardens; car tops and roofs damaged.	Do.

[1] Miles instead of yards.

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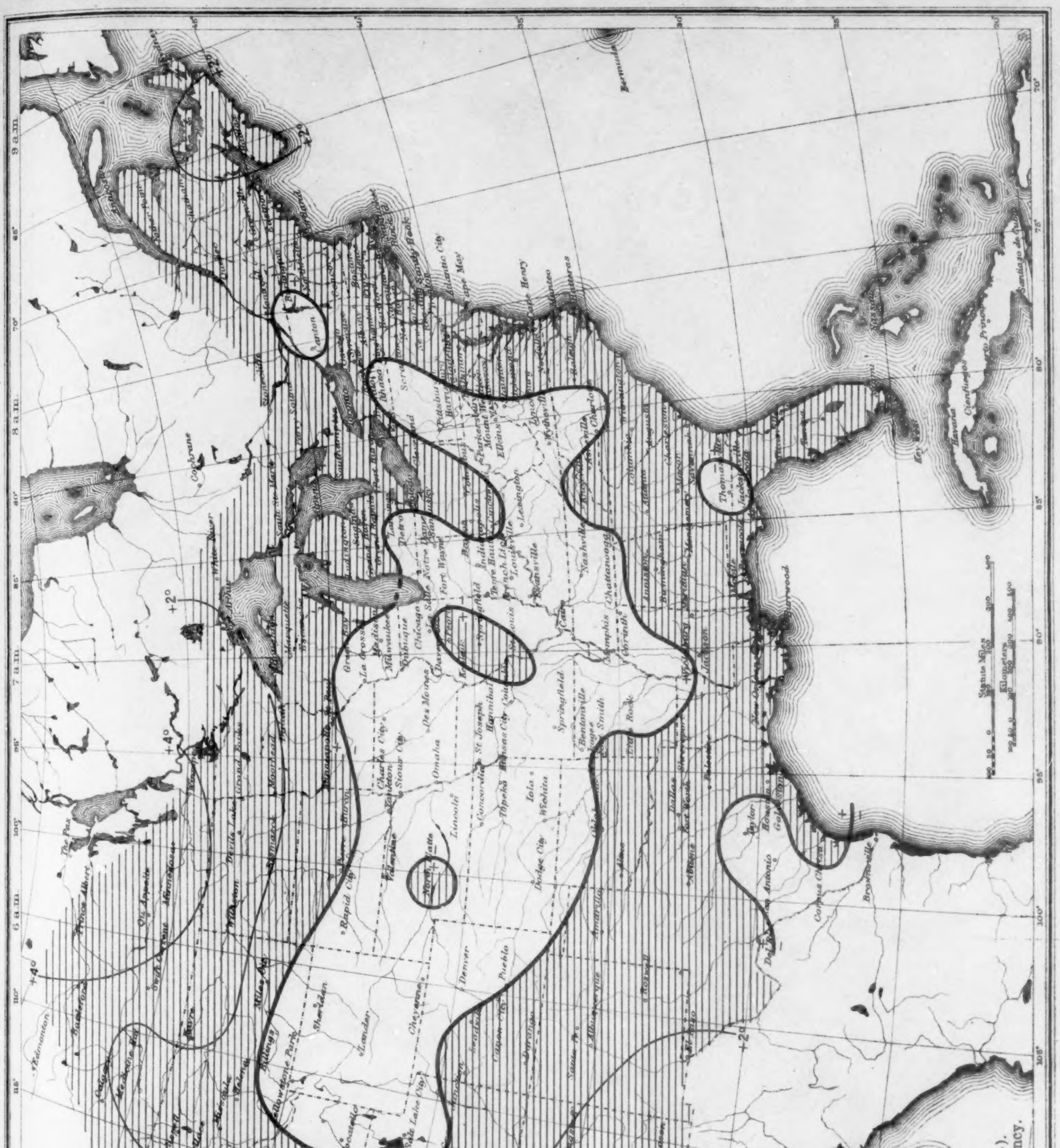
Chart I. Departure (°F.) of the Mean Temperature from the Normal, August 1933

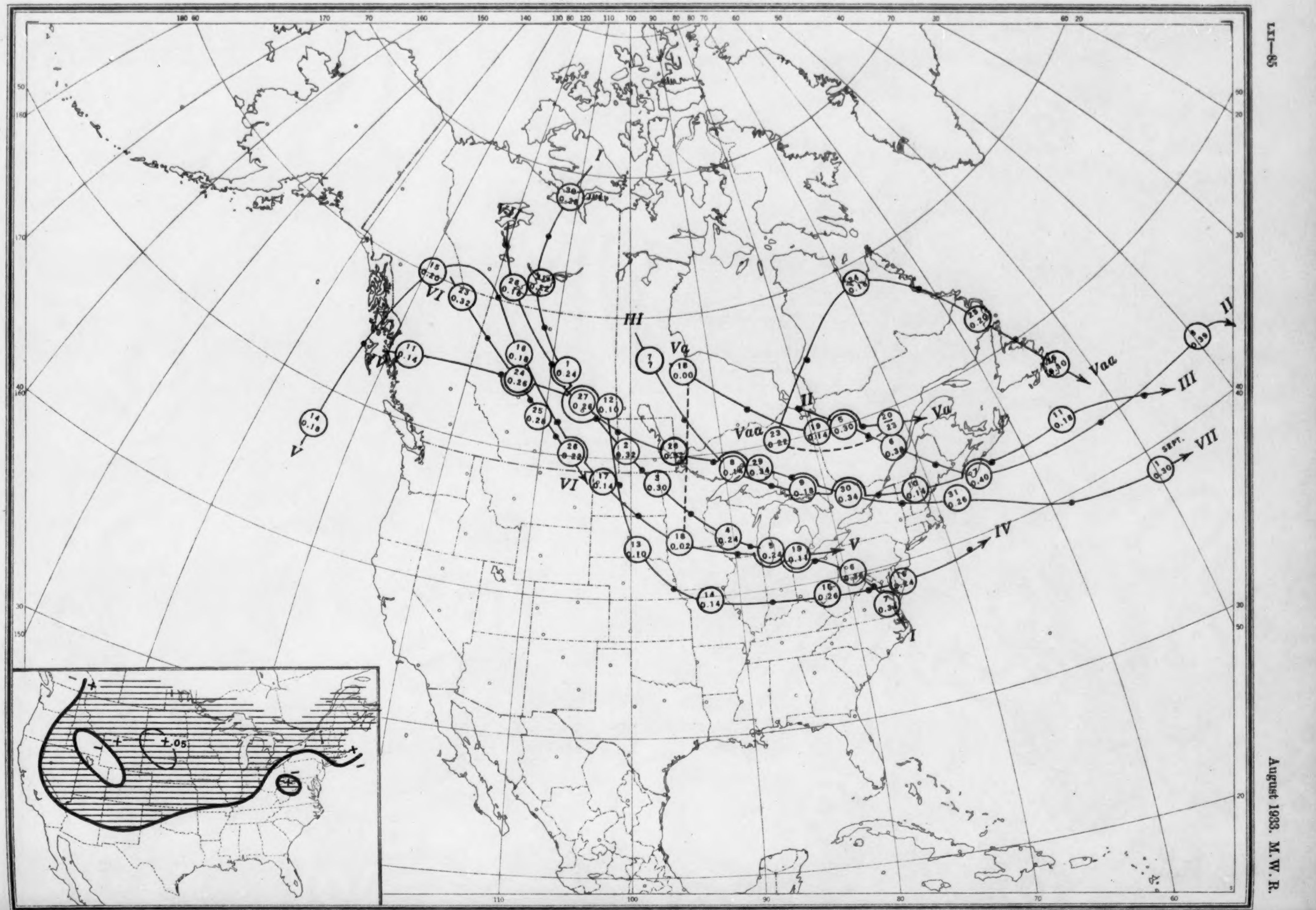
Chart I. Departure (°F.) of the Mean Temperature from the Normal, August 1933



Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, August 1933. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by G. E. Dunn and W. R. Stevens)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

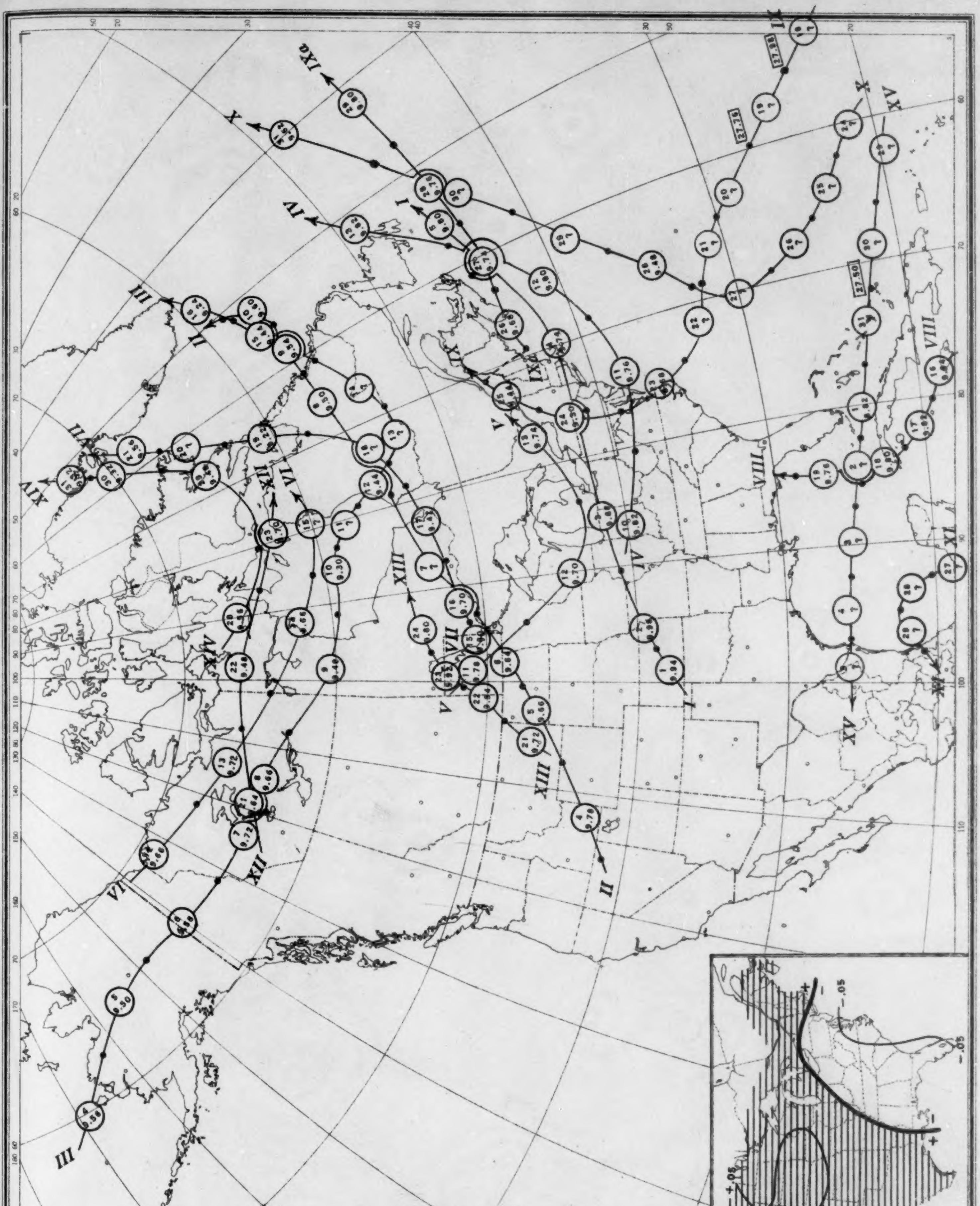
Chart III. Tracks of Centers of Cyclones, August 1933. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by G. E. Dunn and W. R. Stevens)

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, August 1933. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by G. E. Dunn and W. R. Stevens)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, August 1933

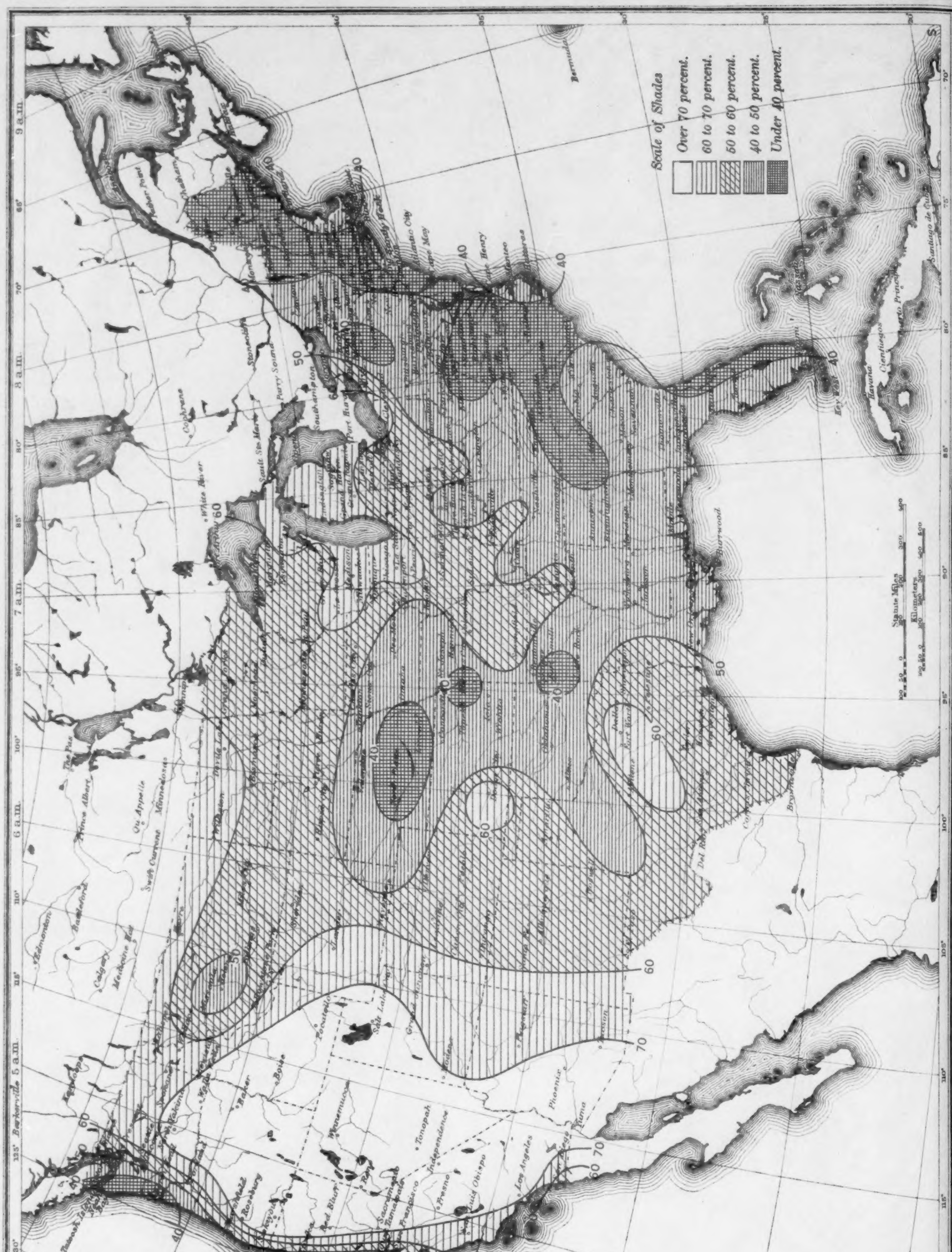


Chart V. Total Precipitation, Inches, August 1933. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, August 1933. (Inset) Departure of Precipitation from Normal

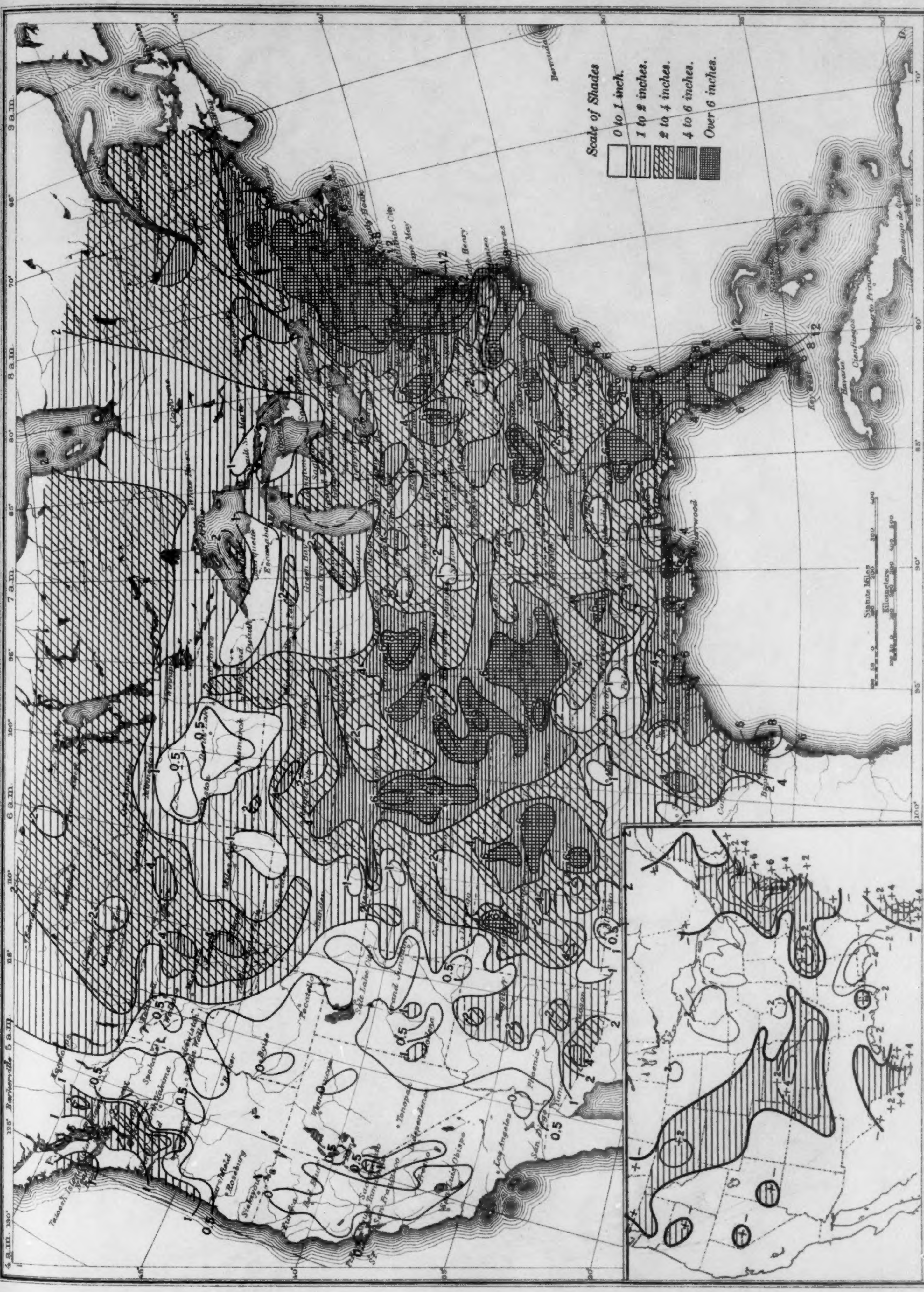


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, August 1933

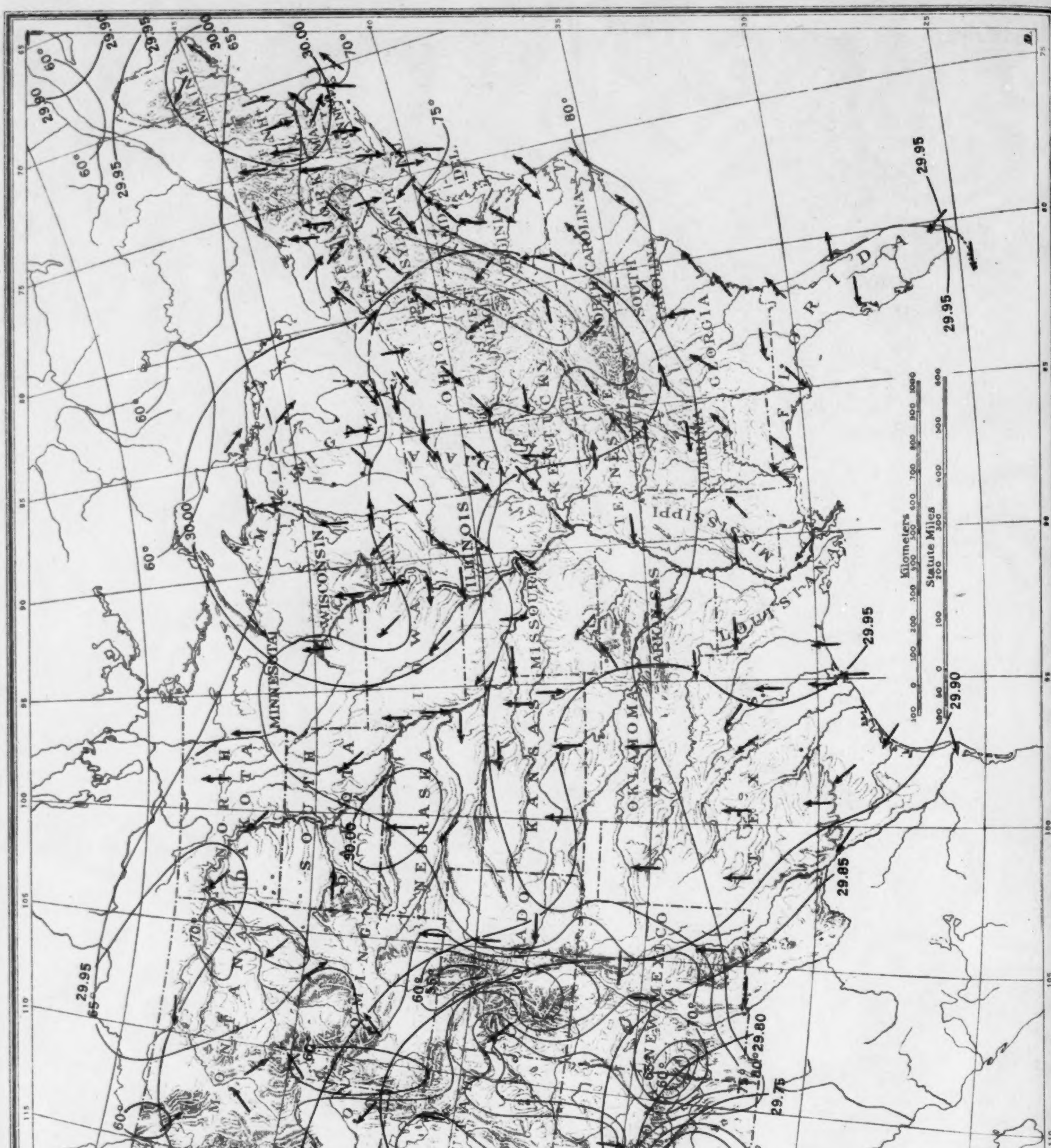


Chart VIII. Weather Map of North Atlantic Ocean, August 6, 1933
(Plotted from the Weather Bureau Northern Hemisphere Chart)

Chart VIII. Weather Map of North Atlantic Ocean, August 6, 1933

(Plotted from the Weather Bureau Northern Hemisphere Chart)

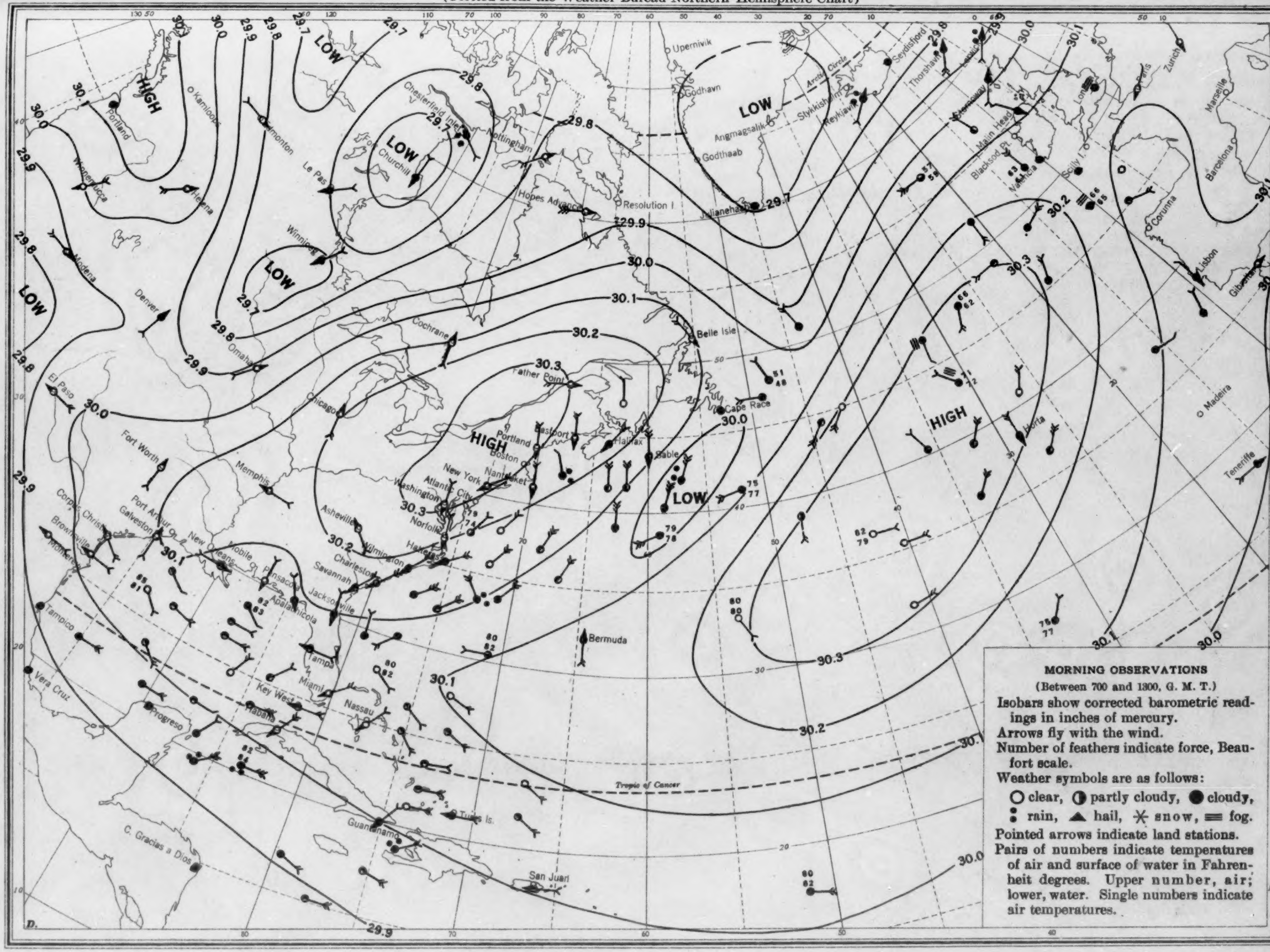


Chart IX. Weather Map of North Atlantic Ocean, August 8, 1933
(Plotted from the Weather Bureau Northern Hemisphere Chart)

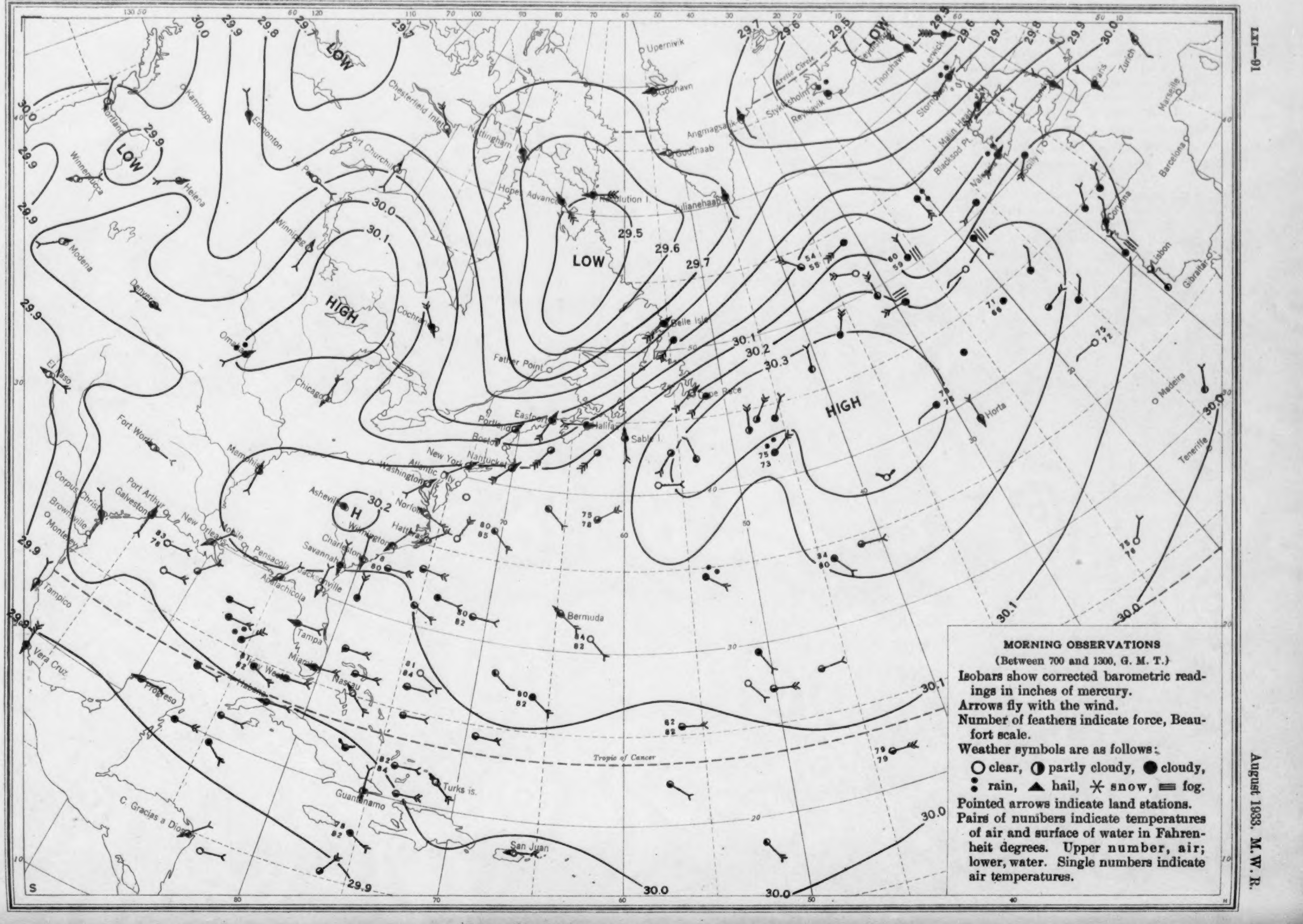


Chart X. Weather Map of North Atlantic Ocean, August 22, 1933
(Plotted from the Weather Bureau Northern Hemisphere Chart)

Chart X. Weather Map of North Atlantic Ocean, August 22, 1933
(Plotted from the Weather Bureau Northern Hemisphere Chart)

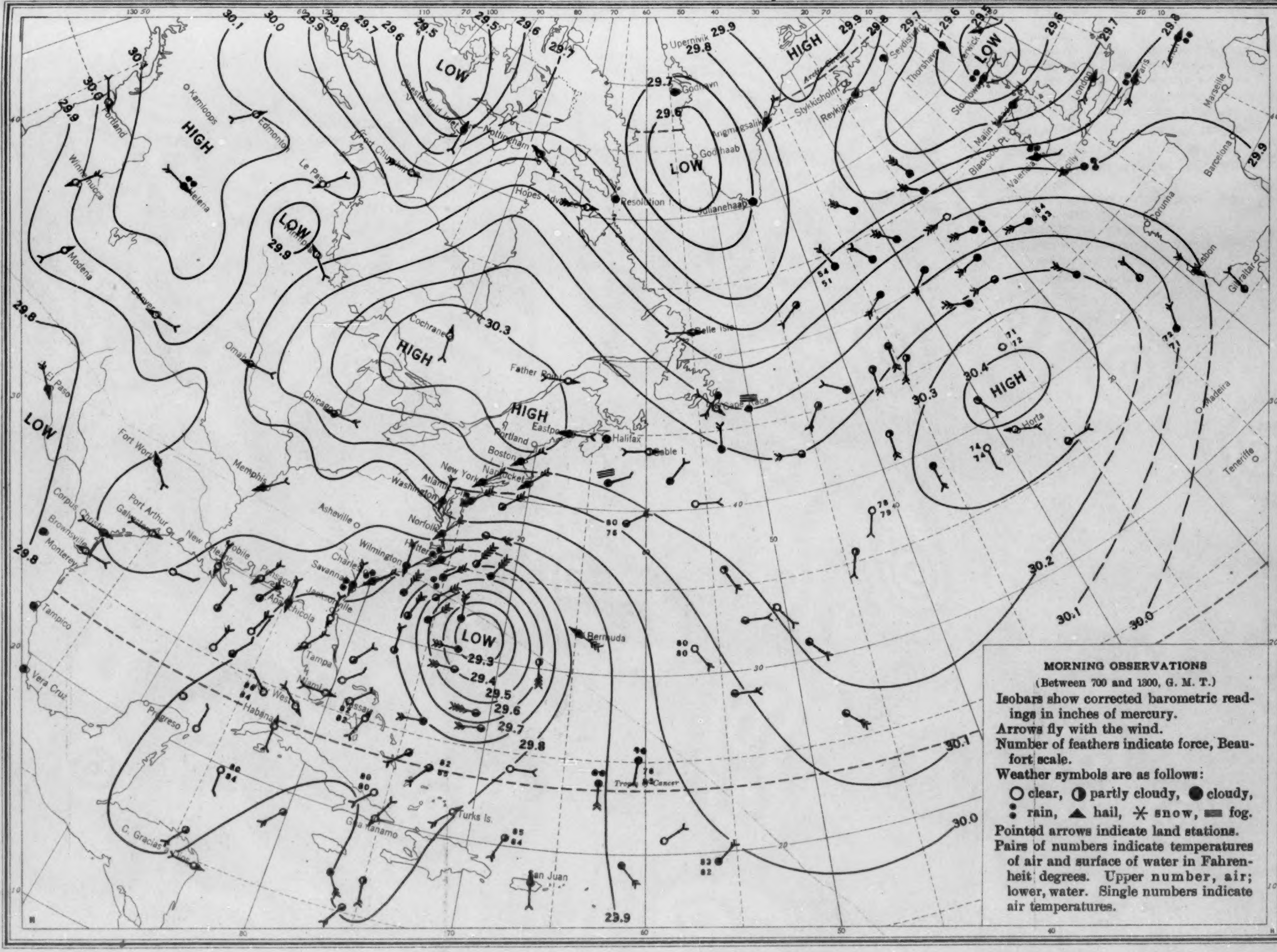
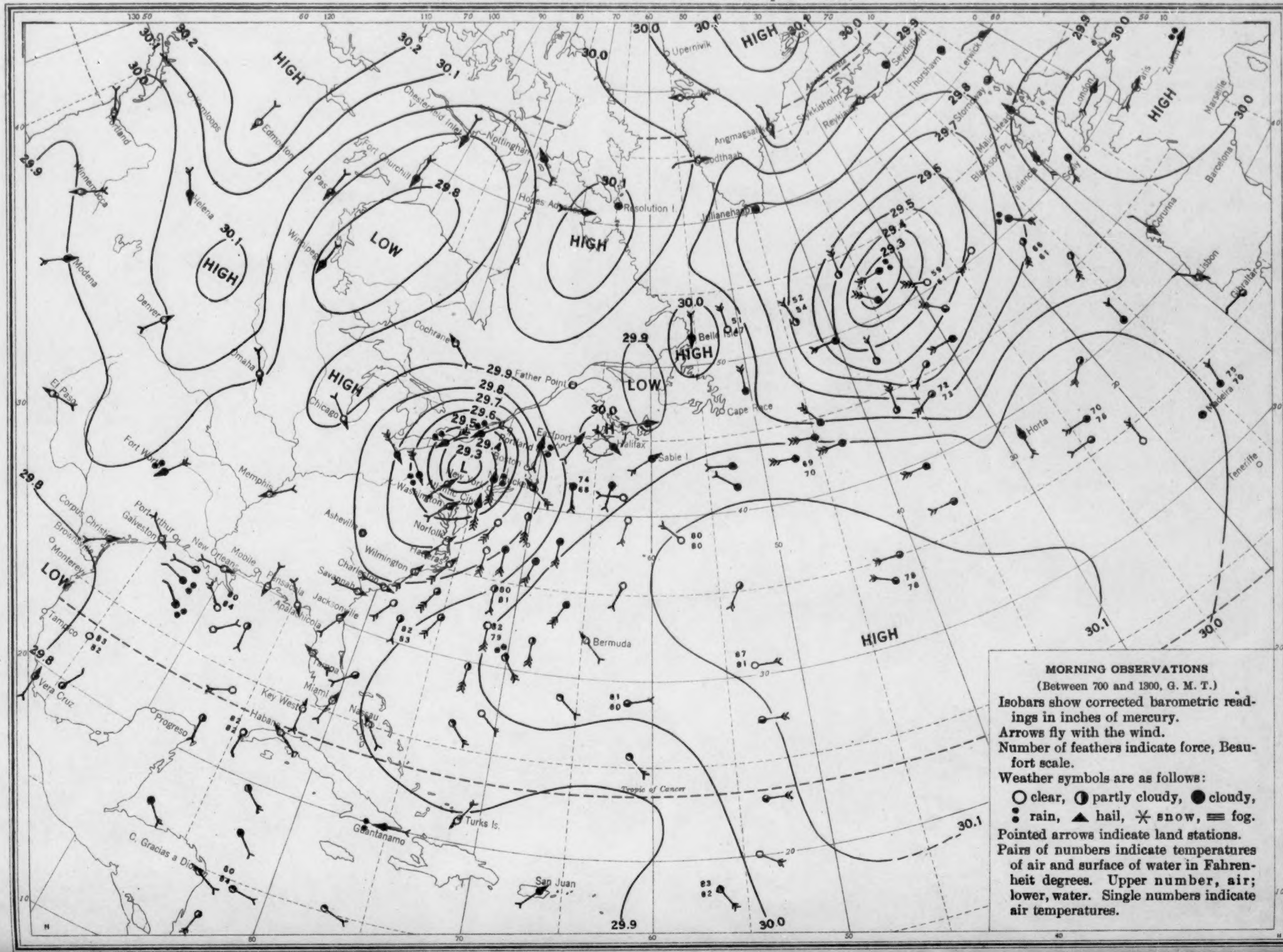


Chart XI. Weather Map of North Atlantic Ocean, August 24, 1933

(Plotted from the Weather Bureau Northern Hemisphere Chart)



MORNING OBSERVATIONS

(Between 700 and 1300, G. M. T.)

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁚ rain, ▲ hail, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.